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Volume I
March 1995

Estimating the Cold War Mortgage

The 1995 Baseline Environmental Management Report

U.S. Department of Energy
Office of Environmental Management

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At a Glance: The 1995 Baseline Environmental Management Report

RESULTS
"Base-Case"

$230 Billion over a 75-year period

- Waste Management – **49%**
- Environmental Restoration – **28%**
- Nuclear Material and Facility Stabilization – **10%**
- Technology Development – **5%**
- Other – **8%**

Top 5 Sites - 70% of costs

- Hanford Site – **21%**
- Savannah River Site – **21%**
- Rocky Flats Site – **10%**
- Oak Ridge Reservation – **10%**
- Idaho Laboratory – **8%**

ASSUMES:

- Significant productivity increases
- Meeting current compliance requirements
- Use of existing technologies

Development of most assumptions occurred at field locations (e.g., degree of cleanup)

EXCLUDED:

- Cleanup where no feasible cleanup technology exists (e.g., Nuclear explosion sites, most contaminated groundwater)
- Cleanup of currently active facilities (e.g., Pantex, Labs)
- Naval Nuclear Propulsion facilities cleanups handled by U.S. Navy.
- Activities during first 5 years of program ($23 billion)

ALTERNATIVE CASES evaluated the effect of:

- Landuse: biggest potential cost impact
- New Technologies
- Waste Management Facilities configuration
- Funding & Schedule
- Residual Risk: inadequate data limited analysis

WHAT DID WE LEARN?

- Total projected environmental costs are comparable to total U.S. nuclear weapons production costs.
- Projected future land use will dramatically affect costs.
- Significant ($24 billion) projected costs to support ongoing programs could be substantially reduced through greater pollution prevention.
- Development of new technologies will reduce certain cleanup costs and make possible other cleanups that are currently infeasible.
- Minimum action to stabilize sites - $170 billion.

ESTIMATES, NOT DECISIONS

- The estimated costs do not reflect final Departmental decisions in many cases. The report is intended to provide a framework for constructive local and national debate about the future of the environmental management program.
- Projected costs significantly exceed current budget targets. Bridging this gap will require renegotiating compliance agreements and some statutory changes, in addition to planned productivity improvements.

For further information, please contact the Center for Environmental Management Information (1-800-736-3282)

Executive Summary

This is the first annual report on the activities and potential costs required to address the waste, contamination, and surplus nuclear facilities that are the responsibility of the Department of Energy's Environmental Management program. The Department's Office of Environmental Management, established in 1989, manages one of the largest environmental programs in the world—with more than 130 sites and facilities in over 30 States and territories. The primary focus of the program is to reduce health and safety risks from radioactive waste and contamination resulting from the production, development, and testing of nuclear weapons. The program also is responsible for the environmental legacy from, and ongoing waste management for, nuclear energy research and development, and basic science research. In an attempt to better oversee this effort, Congress required the Secretary of Energy to submit a Baseline Environmental Management Report with annual updates.

The 1995 Baseline Environmental Management Report provides life-cycle cost estimates, tentative schedules, and projected activities necessary to complete the Environmental Management program.

The 1995 Baseline Environmental Management Report (Baseline Report) provides life-cycle cost estimates, tentative schedules, and projected activities necessary to complete the Environmental Management program. In doing so, it represents the Department's most comprehensive effort to date to develop a clearer picture of the "Cold War Mortgage."

The Cold War Mortgage

During World War II and the Cold War, the United States developed a vast network of industrial facilities for the research, production, and testing of nuclear weapons, known as the "nuclear weapons complex." It includes thousands of large industrial structures such as nuclear reactors, chemical processing buildings, metal machining plants, and maintenance facilities. During the last 50 years, this enterprise manufactured tens of thousands of nuclear warheads and detonated more than a thousand. The Department of Energy, the Federal agency responsible for managing the nuclear weapons complex, manages more than 120 million square feet of buildings and 2.3 million acres of land—an area larger than Delaware, Rhode Island, and the District of Columbia combined.

In addition to creating an arsenal of nuclear weapons, the complex left an unprecedented environmental legacy. Because of the priority on weapons production, the treatment and storage of radioactive and chemical waste was handled in a way that led to contamination of soil, surface water, and ground water and an enormous backlog of waste and dangerous materials. As a result of revelations by the news media and various organizations, as well as studies conducted by the Department of Energy during the last 10 years, this legacy has become increasingly well-known. However, part of the purpose of this report is to establish a more disciplined inventory of the problems and the potential liabilities so it can be used as a management tool.

The cost of dealing with these problems can be considered a "Cold War Mortgage." Much of these costs were deferred during the nuclear arms race. Paying the mortgage will take decades and substantial resources comparable to the level of effort expended for the nuclear weapons production and research activities.

The Environmental Management Program

The Office of Environmental Management was created in 1989 to help address the environmental legacy of nuclear weapons production and other sources such as nuclear research programs.

Activities that encompass the Environmental Management program include: (1) environmental restoration; (2) waste management; (3) nuclear material and facility stabilization; and (4) technology development. Landlord functions (e.g., fire-fighting response, road maintenance, utilities) represent a fifth area, which includes cross-cutting support activities.

These activities are often simplified as "cleanup," but it is clear they involve a lot more than cleanup. Moreover, these activities are not only interrelated (e.g., facilities must be stabilized before they can be decontaminated, and waste must be managed after it is generated as a result of restoration work), but they are also inextricably related to the functions of the Department of Energy and other Federal agencies. For example, the Environmental Management program provides waste management services to the facilities that continue to operate and maintain the nuclear weapons stockpile such as the Los Alamos National Laboratory, the Savannah River Site, and the Kansas City Plant. Additionally, the spent nuclear fuel generated from U.S. Navy vessels is handled by the Environmental Management program.

In addition to these defense support functions, the Environmental Management program supports the variety of basic and applied scientific research facilities operated by the Department of Energy, including Brookhaven National Laboratory, and Fermi National Accelerator Laboratory.

Although most Environmental Management program work involves dealing with the legacy of contamination and the backlog of accumulated wastes, a significant amount involves handling newly generated waste from these programs—all while protecting worker health and safety. This report covers this broad span of Environmental Management program activities. Additional detail regarding these activities is provided in Chapter 2.

What Does the Nation Want to Buy?

The future course of the Environmental Management program will depend on a number of fundamental technical and policy choices, many of which have not yet been made. Ultimately, these decisions will be made on the basis of fulfilling congressional mandates, regulatory direction, and adequate stakeholder input. The cost and environmental implications of alternative choices can be profound. For example, many contaminated sites and facilities could be restored to a pristine condition, suitable for any desired use; they also could be restored to a point where they pose no near-term health risks to surrounding communities but are essentially surrounded by fences and left in place. Achieving pristine conditions would have a higher cost, but may or may not warrant the economic costs and potential ecosystem disruption or be legally required. Resolving such issues will depend on what the Nation wants to buy.

Other key questions that affect the cost of the program include the following:

- What level of residual contamination should be allowed after cleanup?
- Should projects to reduce maintenance costs (i.e., high storage costs pending ultimate disposition of materials) be given priority over certain low-risk cleanup activities? In other words, how should cost affect priorities?
- Should cleanup and waste management proceed with existing technologies or is it

Previous Cost Estimates

The Federal Government last estimated the total cost of environmental liabilities at Department of Energy facilities in 1988 before the end of the Cold War, when the renovation and indefinite operation of the existing nuclear weapons complex was being planned. These cost estimates primarily assessed what was needed to bring installations into compliance with environmental regulations to allow continued weapons production. For example, estimates focused on permitting installations and operation of air and water monitoring systems with limited short-term corrective action at active sites. Little emphasis was placed on more expensive activities such as remedial action at inactive sites. Most estimates ranged from $100 to $300 billion for total program cost. Even higher estimates were produced by speculative extrapolation without the benefit of the type of field data on which this report is based.

The Baseline Report is substantially different – both the results and the methodology – from past estimates for a number of reasons. First, the Base Case estimate in this report is based on a "bottom up" approach using large amounts of data and assumptions collected from field offices, rather than centralized estimating processes, which were used in previous estimates. This method resulted in more realistic land-use assumptions and, consequently, substantially lower costs than previous cost estimates. Second, this report does not attempt to provide cost estimates for cleanup activities that are not technically feasible using existing technologies. Such costs, which were included in some previous estimates, do not make sense because complete cleanup using existing technologies cannot be attained at any price for certain contamination situations such as nuclear weapons test residues or large areas of contaminated ground water and river system sediments. Third, the activities for which estimates are provided in this report reflect the Department's significantly reduced nuclear weapons production requirements. Finally, the Baseline Report also reflects a greater understanding of the nature and extent of contamination, as well as broader program support responsibilities than assumed for previous estimates. As a result of these differences, this Baseline Report is not comparable in scope and is substantially improved in the level of detail and integration over past estimates.

prudent, in some cases, to wait for the development of improved technologies? What criteria should guide decisions on this issue?

- Should waste treatment, storage, and disposal activities be carried out in decentralized, regional, or centralized facilities? How are issues of equity among states factored into configuration decisions?

The most cost-effective way to resolve these issues is to engage in a broad debate to assess the costs, risks, and other public trade-offs associated with different approaches. The 1995 Baseline Report lays the foundation for this constructive discussion. It describes where the Environmental Management program is headed, according to current assumptions, and illustrates potential impacts if these assumptions vary.

Estimating Costs in the Face of Large Uncertainties

Estimating the cost of future activities requires making assumptions about what those activities will be and is inherently uncertain. The uncertainty stems from:

- lack of characterization of the problems. For example, of the 10,500 hazardous substance release sites addressed in this report, only one-fourth have been fully characterized.
- lack of knowledge about what remedies will be effective or considered acceptable to regulators and the public, or what level of human health and environmental protection is sought through these remedies.

The Baseline Report Is Not a Budget Document

The purpose of the Baseline Report is to provide a total long-term (life-cycle) cost estimate for the Environmental Management program. The Baseline Report is not intended to be a budget document, and none of the estimates given in the document should be interpreted as Federal budget requests.

Furthermore, the schedule of activities presented in the Baseline Report should not be interpreted as establishing specific long-term priorities or construed as a definitive basis for planning specific projects. Too many decisions that will affect the strategic long-term goals for the program are yet to be made. The issues underlying these decisions, such as future land use, funding availability, and acceptable levels of residual contamination, will be resolved over several years in conjunction with broad public discussion. Fostering and informing this discussion is a key purpose of this analysis.

- lack of fundamental economic, social, and defense related decisions that affect the future use of land and facilities. For example, policy decisions related to the role of sites for nuclear nonproliferation and defense readiness will define the future mission for the Department's nuclear weapons complex. These policy decisions will affect the continued operations of some installations, including future land-use options and the final disposition of nuclear materials.
- lack of technical remedies for the problems. The contamination of soils deep underground from nuclear tests in Nevada is one such case. The costs to remediate these types of sites were excluded from the cost estimate, not because of a departmental policy to ignore such problems, but because no effective remediation technology currently exists.
- lack of defined program duration. The length of the program—approximately 75 years—is sufficient to introduce a variety of uncertainties into any cost and schedule estimate.

Despite these uncertainties, there is an important advantage in attempting to estimate costs before all this information is available or these decisions have been made: the cost consequences of different technical and policy options can be explicitly analyzed and debated to make wise decisions in an open manner. Hence, this first baseline analysis serves as a benchmark to gauge future progress in defining, as well as solving, the problems. In addition to better facilitating program management, this is exactly the value of this study.

The Department expects assumptions about the program and the resulting cost-and-schedule estimates to change in future Baseline Reports as new information becomes available, and ongoing decisionmaking processes evolve, thereby reducing uncertainty.

Approach Used For Estimating Costs and Schedules

The Department used two methods for estimating costs in this report: the "Base Case" and "Alternative Cases." The Base Case was used to represent current views of the most likely set of activities. Because many assumptions are preliminary (i.e., they were made to estimate costs for activities that will happen decades from now) and will undoubtedly change in many cases, alternative cases are presented.

Estimates of Base Case costs and schedules provided in the Baseline Report are based largely on site-specific assumptions regarding future land use; treatment, storage, and disposal facility needs; and the technologies to be used at the site. These assumptions were developed at individual sites and reflect specific regulatory requirements and site-specific planning efforts.

Alternative case cost and schedule estimates were developed by Department of Energy

Headquarters to show the potential cost impacts of changing assumptions in four key areas: future land use, program funding and scheduling, technology development, and waste management configurations.

Base Case Assumptions

Because the Baseline Report uses currently available information, the Base Case estimates reflect a broad range of assumptions. These assumptions reflect potential decisions regarding the scope and pace of the Environmental Management program.

In addition, the Department excluded projects with no current feasible remediation approach from this year's Baseline Report scope. These projects include large contaminated river systems like the Columbia, Clinch and Savannah rivers and the Nevada Test Site's underground weapons test area. The cost estimate would obviously be higher if some remediation were assumed for these areas for which complete cleanup is not technically feasible with existing technologies. However, because no effective remedial technology could be identified, no basis for estimating cost was available. A more detailed description of the Base Case is provided in Chapter 3.

Note: Volume II provides summary assumptions and results for <u>each site</u> as well as site personnel contacts for additional details.

Environmental Restoration

Usually described as "cleanup," environmental restoration encompasses a wide range of activities such as stabilizing contaminated soil; treating ground water; decontaminating and decommissioning nuclear reactors and process buildings, including chemical separation plants; and exhuming buried waste.

The Base Case estimate for environmental restoration was developed by compiling data from approximately 10,500 "release sites," grouped into 614 subprojects or "operable units."

The assumptions used in developing the Base Case were virtually all developed at the particular site or field office, usually in consultation with regulatory officials.

Although each site generally used its own assumptions for developing the Base Case estimate, several fundamental assumptions were used by all sites. These general assumptions include the following:

- use of existing technologies;
- compliance with existing or reasonably anticipated regulatory/negotiated agreements or Energy Department Orders; and
- remedies considered technically and environmentally reasonable and achievable by local project managers and appropriate regulatory authorities.

To the extent that restricted future land use was assumed by field offices to estimate costs, it reflects current or anticipated agreements with regulators and /or stakeholders, or interim determinations based on what remediation goal is achievable using existing technologies. The Administration has proposed legislative changes to the Superfund law to allow such considerations to be used in selecting remedies to a greater extent. In some cases, the cost estimates reflect projected remedial actions that assume these changes to the law because unrestricted future land use was not reasonably achievable using existing technologies. The particular assumptions used varied among sites because of the "bottom up" method used for estimating Base Case costs in this report.

Waste Management

The Department is responsible for storing, treating, and disposing of an extraordinary array of wastes and spent nuclear fuel. These wastes include a variety of physical forms (e.g., solids, liquids, and sludges); chemical types (i.e., solvents, metals, and salts); and sources (e.g., high–level waste from reprocessing, spent nuclear fuel from production reactors, and naval reactors); transuranic waste from

Key Waste Management Assumptions

High-Level Waste

- Continue storage in tanks at Hanford, Savannah River Site, West Valley Demonstration Project, and in calcine bins at Idaho National Engineering Laboratory.
- Vitrify and dispose of all high level wastes in geologic repository (available beginning in 2015).

Spent Nuclear Fuel

- Continue storage at 10 sites with costs for new wet and dry storage facilities estimated.
- No reprocessing.
- Dispose in geologic repository.

Transuranic Waste

- Continue storage at 10 sites.
- Treat as necessary to meet disposal criteria at the Waste Isolation Pilot Plant (starting in 1998).

Low-Level and Low-Level Mixed Waste

- Storage until treatment at 34 sites to meet minimum disposal requirements.
- Disposal at Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, Oak Ridge Reservation, and Savannah River Site.
- Western sites using shallow land disposal and eastern sites using engineered disposal techniques.

plutonium operations; and low-level waste, which includes virtually everything else that is radioactive waste.

Most of the wastes included in the Baseline Report were generated during the production of nuclear weapons during the Cold War. Smaller amounts of the existing waste legacy resulted from various nuclear and other research projects. In the future, the Department expects that the quantities of waste from these sources will decrease as pollution prevention efforts become more effective, and nuclear weapons production activity decreases, and that a new source of waste will become increasingly important: secondary waste generated as a result of environmental restoration and nuclear material and facility stabilization.

Costs for waste management cover all life-cycle phases from planning through decommissioning. The Base Case reflects site-specific planning assumptions, which may include the use of commercial facilities (e.g., hazardous waste treatment and disposal). Costs were compiled from existing program cost estimates for high-level waste and spent nuclear fuel and from standardized calculations designed to estimate treatment, storage, and disposal costs based on predicted waste throughput for transuranic, low-level, low-level mixed, and hazardous wastes.

Nuclear Material and Facility Stabilization

With the end of the Cold War, production of most nuclear weapons materials has been indefinitely halted. Consequently, many Department of Energy facilities are not needed for their previous missions. Before "cleanup" can safely occur at many sites, however, the facilities and the nuclear material they contain must be stabilized. Stabilization entails removal of stored raw materials, stored finished products, and in-process materials at production facilities, which were simply turned off. Because of the urgent risks associated with these dangerous materials, this work is one of the highest priorities for the Environmental Management program. Also, the cost of maintaining facilities before stabilization is usually significantly higher than after it is completed.

The Base Case estimate for nuclear material and facility stabilization activities was built on cost estimates for stabilizing 22 different types of facilities as well as the costs for maintaining them before and after stabilization. In this way, the source of the Base Case estimates is somewhat different than that for waste management and environmental restoration

activities. Because of limited data and experience, nuclear material and facility stabilization Base Case estimates are largely extrapolated from available data regarding the 22 categories of facilities for the number of facilities known to exist in each category.

The strategy for the Environmental Management program is to address urgent risks first and then pace the subsequent final cleanup with the availability of effective technologies, funding, and legal requirements. To implement this strategy, the Department recently completed an inventory of surplus "assets" (i.e., buildings, reactors, structures, etc.); identified high risks among them; and began transferring management responsibility and performing stabilization work. The Base Case estimates assume that:

- 3,500 contaminated facilities are being transferred from other Department of Energy programs to the responsibility of the Environmental Management program;
- these facilities will require 10 years of surveillance and maintenance, followed by 5 years of stabilization activities and 2 years of post-deactivation surveillance and maintenance before final decontamination or disposition;
- most nuclear material and facility stabilization activities will occur in later years because these activities are not typically driven by legal requirements (a reevaluation of this sequence may be warranted based on results of the risk report to be completed in June 1995 and renegotiation of compliance agreements with regulators); and
- surplus plutonium scraps and residues must be stabilized, safeguarded, and dispositioned. The Environmental Management program currently is responsible for approximately 26 metric tons of plutonium in these various forms. The Department currently is involved in a process to decide on the future disposition of surplus plutonium and what quantities of plutonium will be considered surplus.

Technology Development

The Environmental Management program manages a national program of applied research, development, demonstration, testing, and evaluation of technologies. These technologies support environmental restoration, nuclear material and facility stabilization, and waste management. Examples of savings from specific technologies are discussed in Chapter 5 of the report.

Landlord

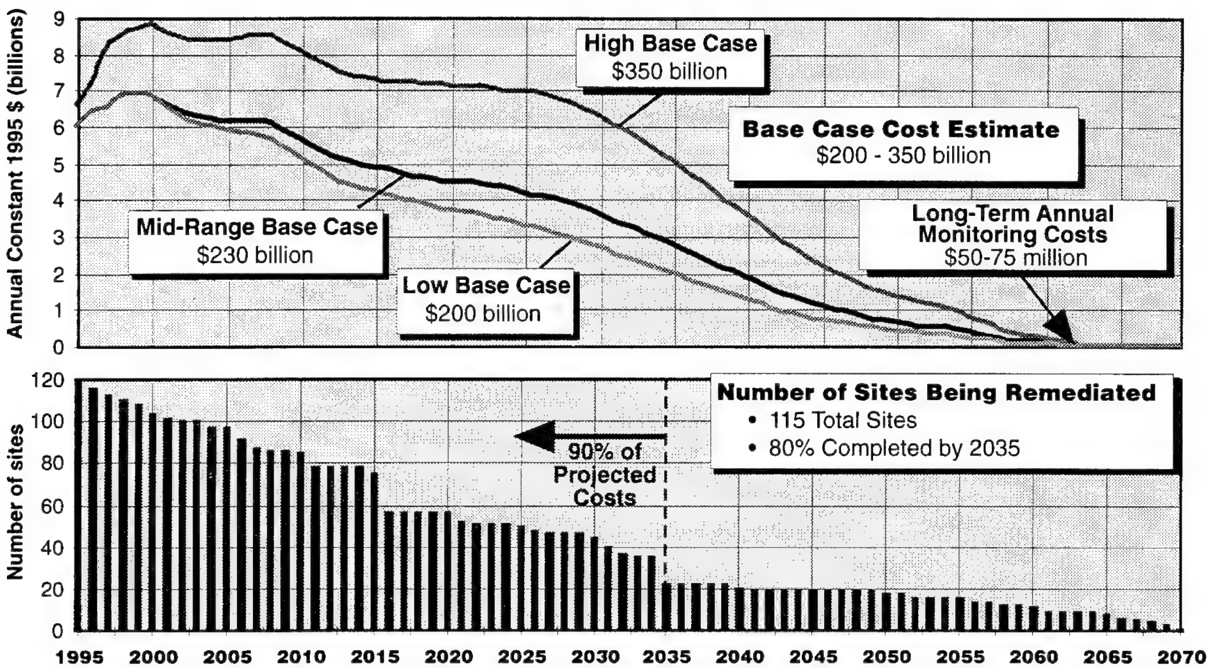
Landlord activities include such services as safeguards and security, transportation, property management, and emergency preparedness (e.g., fire and medical response). The Base Case includes costs for landlord activities at the 10 installations where the Office of Environmental Management has landlord responsibility.

Results

The Base Case cost estimate begins in 1995 and ends in approximately 2070, when environmental management activities are projected to be substantially completed. The estimate does not include costs expended since the program's formal inception in October 1989—about $23 billion–or costs incurred before 1989. Nor does it include costs beyond 2070 for long-term surveillance and maintenance, which are estimated at about $50-75 million per year. These costs are assumed to continue indefinitely after a disposal site or restricted access area is closed.

Under the Base Case, the life-cycle cost estimate for the Department of Energy's Environmental Management program ranges from $200 to $350 billion in constant 1995 dollars, with a mid-range estimate of $230 billion. Figure 1 graphically depicts the life-cycle cost profiles. This includes not only the $172 billion for dealing with the nuclear weapons complex legacy, but $24 billion for future wastes from nuclear weapons activities, and $34 billion for

Figure 1. Base Case Cost and Schedule Estimate



past and future wastes from other activities. The projected costs for treatment, storage, and disposal of waste generated by ongoing defense and research activities is $19 billion. The significant projected cost for support for future ongoing programs indicates the value of vigorous pollution prevention efforts to reduce these costs and threats.

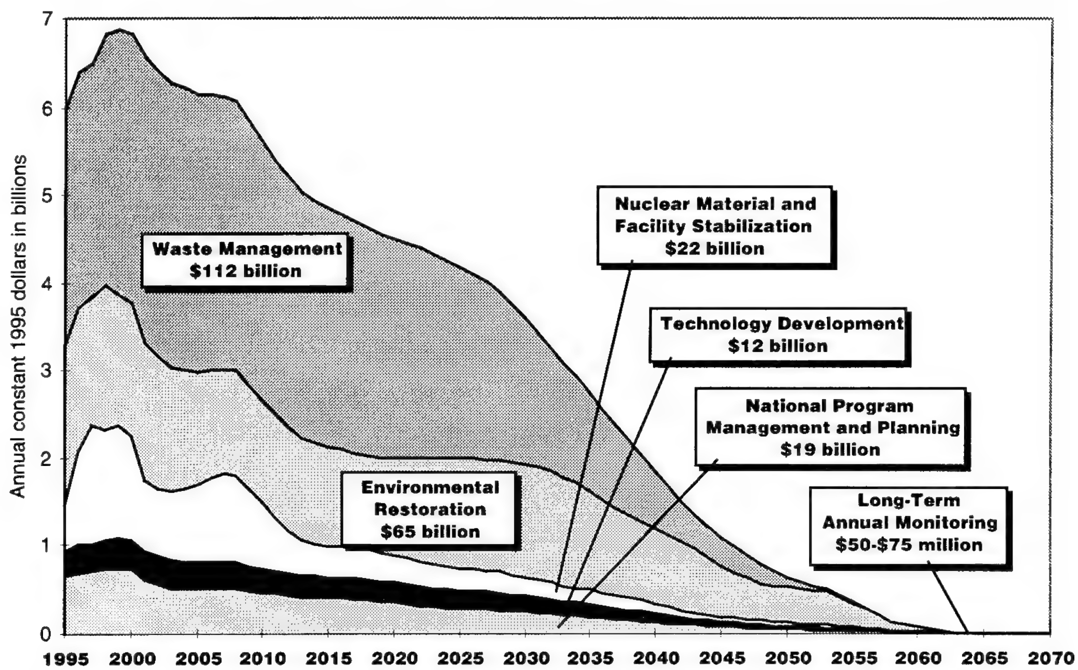
The range of the cost estimate varies depending on the assumed level of productivity over the life of the program as described below.

- The mid-range total program estimate of $230 billion reflects a planned 20-percent increase in productivity and efficiency over the next 5 years, plus an annual 1-percent productivity improvement over the remaining life of the program.
- The low-end estimate of $200 billion reflects a more aggressive efficiency and productivity improvement program—20-percent for the next 5 years as in the mid-range total estimate, and subsequent annual improvements of nearly 2 percent (a number commonly used by the private sector in today's business climate).
- The high-end estimate of $350 billion reflects costs if current levels of inefficiency and productivity were sustained over the program's life.

These levels of efficiency improvement are not only needed and planned, they are attainable. The Environmental Management program already has achieved significant improvements in efficiency and productivity. From FY 1994 to FY 1996, the program will have saved more than $2.1 billion through greater productivity.

Although the total life-cycle estimate is derived from a 75-year program duration, more than 90 percent of the life-cycle cost estimate reflects activities projected to occur during the next 40 years. The remaining costs are primarily for the operation of large waste treatment facilities at a limited number of sites. In 2070, given the Base Case assumptions, access will be restricted at the large, isolated Department of Energy sites with existing burial grounds. These sites

Figure 2. Mid-Range Base Case Cost Profile for Major Elements of the Environmental Management Program



include certain sections of the Hanford Site, Idaho National Engineering Laboratory, Savannah River Site, Nevada Test Site, Oak Ridge, Los Alamos National Laboratory, and the Waste Isolation Pilot Plant. At smaller Department of Energy sites, such as the Mound Site in Ohio or the Pinellas Plant in Florida, where contamination has been contained in place, future use is expected to be limited to industrial purposes.

Small non-Department sites or sites near heavily populated areas or water sources are assumed to be released for residential or industrial use. Examples include the General Atomics Site at La Jolla, California, and Battelle Columbus Laboratories in Columbus, Ohio.

Figure 2 shows cost estimates for the Environmental Management program under the mid-range Base Case estimate. The cost estimate is divided among the five major elements of the program: waste management, environmental restoration, nuclear material and facility stabilization, program management, and technology development.

The Administration's Budget and the 1995 Baseline Report

The Administration has established budget targets for the next 5 years that reflect the allocation of resources among competing national priorities, including lower taxes and deficit reduction. These targets move the Environmental Management program from $6.6 billion in FY 1996 to $5.5 billion in FY 2000 in current dollars. This equates to a target of $4.8 billion in constant 1995 dollars in FY 2000. For purposes of this comparison, this target was assumed to remain unchanged over the life of the Environmental Management program.

A shortfall remains between the Base Case cost estimate (the estimated costs of meeting the Department's compliance agreements) and the FY 1996 funding request and outyear targets. For the high Base Case estimate of $350 billion, this shortfall would be about $100 billion over the next 40 years.

For the mid-range estimate of $230 billion, the savings of about $8 billion from the assumed 20-percent productivity improvement over the next 5 years begins to bridge this gap. Even with these savings, however, a shortfall remains of about $7 billion through FY 2000. The total projected shortfall for the mid-range cost estimate is $24 billion until 2015, at which point the projected budget target would match the projected needs. Figure 3 compares the Baseline Report cost estimate and the administration's FY 1996 budget and outyear projections.

The Department is addressing this shortfall in several ways. First, it has reduced the cost of doing business by streamlining the contractor workforce and negotiating and recompeting contracts. Second, the Department is renegotiating compliance agreements for various sites and installations, many of which were crafted during a different budget climate. In addition, the Administration has proposed legislative improvements to Superfund to make it work better and cost less. These changes would include greater opportunities to consider future land use in remedy selection and potential risks to workers.

Base Case Estimate by State and Site

Further examination of projected costs by State and site shows where the mid-range Base Case would be incurred (see Table 1):

- Washington, South Carolina, Tennessee, Colorado, and Idaho account for $170 billion over the life of the Environmental Management program (71 percent).
- The most costly sites are the Hanford Site (Washington); the Savannah River Site (South Carolina); the Rocky Flats Environmental Technology Site (Colorado); the K-25 Site, the Y-12 Plant, and the Oak Ridge National Laboratory (Tennessee); and the Idaho National Engineering Laboratory.

Figure 3. Comparison between the Base Case Report Cost Estimates and the Administration's Budget Projection

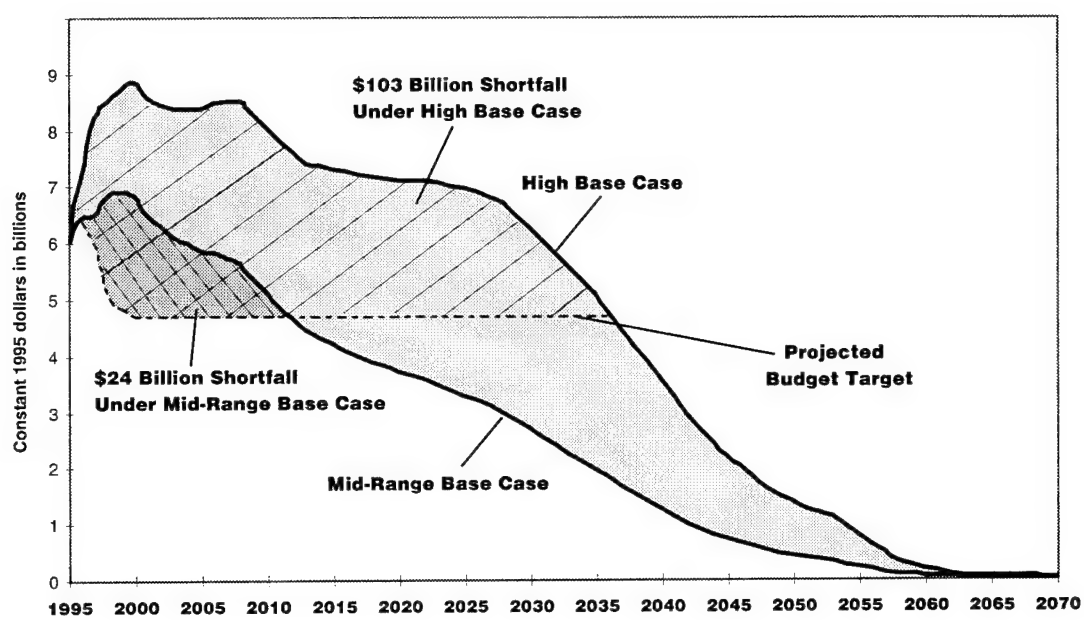


Table 1. Mid-Range Base Case Estimated by State and Site

Site	Mid-Range Base Case Cost (Constant 1995 $ in Millions)	Percentage of Total Mid-Range Base Case Cost
Alaska	***2***	***<1%***
Nevada Offsite* - Alaska	2	<.01%
Arizona	***139***	***<1%***
Completed UMTRA S&M** - Arizona	139	0.06%
California	***2,273***	***0.98%***
Energy Technology Engineering Center	249	0.11%
General Atomics	12	0.01%
General Electric Vallecitos Nuclear Center	18	0.01%
Geothermal Test Faciity	6	<.01%
Laboratory for Energy Related Health Research	34	0.01%
Lawrence Berkeley Laboratory	208	0.09%
Lawrence Livermore National Laboratory	1,521	0.66%
Oxnard	13	0.01%
Sandia National Laboratories - Livermore	92	0.04%
Stanford Linear Accelerator Center	119	0.05%
Colorado	***23,294***	***10.10%***
Completed UMTRA S&M - Colorado	7	<.01%
Grand Junction Project Office Site	707	0.31%
Gunnison	14	0.01%
Maybell	23	0.01%
Naturita	26	0.01%
Rifle	34	0.01%
Rocky Flats Environmental Technology Site	22,455	9.74%
Nevada Offsite - Colorado	3	<.01%
Slick Rock	26	0.01%
Connecticut	***3***	***<.01%***
FUSRAP*** - Connecticut	3	<.01%
Florida	***189***	***<1%***
Pinellas Plant	189	0.08%
Idaho	***18,658***	***8.09%***
Argonne National Laboratory - West	229	0.10%
Completed UMTRA S&M - Idaho	<1	<.01%
Idaho National Engineering Laboratory	18,430	7.99%
Illinois	***612***	***<1%***
Argonne National Laboratory - East	527	0.23%
Fermi National Accelerator Laboratory	76	0.03%
FUSRAP - Illinois	1	<.01%
Site A/Plot M	8	<.01%
Iowa	***12***	***<1%***
Ames Laboratory	12	0.01%
Kentucky	***3,390***	***1.47%***
Maxey Flats	221	0.01%
Paducah Gaseous Diffusion Plant	3,368	1.46%
Maryland/District of Columbia	***30,143***	***13.07***
FUSRAP - Maryland	7	<.01%
Environmental Management Headquarters****	30,136	13.07%
Massachusetts	***14***	***<1%***
FUSRAP - Massachusetts	14	0.01%
Michigan	***1***	***<1%***
FUSRAP - Michigan	1	<.01%
Mississippi	***3***	***<1%***
Nevada Offsite - Mississippi	3	<.01%
Missouri	***1,074***	***0.47%***
FUSRAP - Missouri	388	0.17%
Kansas City Plant	312	0.14%
Weldon Spring Site Remedial Action Project	373	0.16%

*Nevada Offsite are locations where nuclear detonations occurred and environmental management activities are managed by the Nevada Operations Office.
** UMTRA S&M is the acronym for Uranium Mill Tailings Remedial Action projects with long-term Surveillance and Maintenance activities.
***FUSRAP is the acronym for the Formerly Utilized Sites Remedial Action Program.
****Approximately 71 percent of these costs are distributed across Environmental Management sites.

Table 1. Mid-Range Base Case Estimated by State and Site (continued)

Site	Mid-Range Base Case Cost (Constant 1995 $ in Millions)	Percentage of Total Mid-Range Base Case Cost
Nebraska	***<1***	***<1%***
Hallam Nuclear Power Plant	<1	<.01%
Nevada	***2,472***	***1.07%***
Nevada Test Site	2,443	1.06%
Nevada Offsite - Nevada	29	0.01%
New Jersey	***440***	***<1%***
FUSRAP - New Jersey	322	0.14%
Princeton Plasma Physics Laboratory	118	0.05%
New Mexico	***9,647***	***4.18%***
Albuquerque Operations Office	456	0.20%
Ambrosia Lake	<1	<.01%
Completed UMTRA S&M - New Mexico	3	<.01%
Inhalation Toxicology Research Institute	19	0.01%
Los Alamos National Laboratory	3,304	1.43%
Nevada Offsite - New Mexico	10	<.01%
Sandia National Laboratories - New Mexico	890	0.39%
South Valley Site	18	0.01%
Waste Isolation Pilot Plant	4,948	2.15*
New York	***4,003***	***1.74%***
Brookhaven National Laboratory	460	0.20%
FUSRAP - New York	273	0.12%
Separations Process Research Unit	112	0.05%
West Valley Demonstration Project	3,157	1.37%
North Dakota	***22***	***<1%***
Belfield/Bowman	22	0.01%
Ohio	***11,743***	***5.09%***
Battelle Columbus Laboratories	110	0.05%
Fernald Environmental Management Project	4,186	1.82%
FUSRAP - Ohio	197	0.09%
Mound Plant	1,539	0.67%
Piqua Nuclear Power Plant	<1	<.01%
Portsmouth Gaseous Diffusion Plant	5,575	2.42%
Reactive Metals, Inc.	135	0.06%
Oregon	***3***	***<1%***
Completed UMTRA S&M - Oregon	3	<.01%
Pennsylvania	***3***	***<1%***
Completed UMTRA S&M - Pennsylvania	3	<.01%
South Carolina	***48,174***	***20,90%***
Savannah River Site	48,174	20,90%
Tennessee	***24,812***	***10.76%***
Oak Ridge Y-12 Site	4,127	1.79%
Oak Ridge Reservation	277	0.12%
Oak Ridge K-25 Site	12,662	5.49%
Oak Ridge Associated Universities	18	0.01%
Oak Ridge National Laboratory	7,729	3.35%
Texas	***582***	***<1%***
Completed UMTRA S&M - Texas	21	0.01%
Pantex Plant	562	0.24%
Utah	***140***	***<1%***
Completed UMTRA S&M - Utah	8	<.01%
Monticello Millsite and Vicinity Properties	131	0.06%
Washington	***48,671***	***21.11%***
Hanford Site	48,671	21.11%
Wyoming	***25***	***<1%***
Completed UMTRA S&M - Wyoming	25	0.01%
Total	**$230 Billion**	**100%**

Alternative Cases

The alternative cases reflect ways the Base Case could change if certain policy decisions were made. The alternative cases analyzed four areas most likely to affect total cost, scope, and pace of the Environmental Management program:

- **land use**—What are the ultimate uses for currently contaminated lands, waters, and structures at each installation?
- **program funding and schedule**—How might activities be prioritized, and how rapidly will this money be spent?
- **technology development**—How might future technologies influence the Environmental Management program?
- **waste management configurations**—Where and how will we treat, store, and dispose of wastes?

Land Use

How land will be used after environmental remediation dictates the type and extent of remedial approaches, and thus, total costs. The Base Case estimate in this report is based on a "bottom up" approach using large amounts of data and assumptions collected from field offices, rather than centralized estimating processes. This method resulted in more realistic land-use assumptions and, consequently, substantially lower costs than previous cost estimates. For comparison, total program costs were analyzed for a range of alternative future land uses, ranging from most to least restricted. Figure 4 depicts a contiuum of land use ranging from totally restricted to totally unrestricted use.

The most restricted case involves containing existing contamination in place and restricting public access thereafter. The least restricted land use requires removing or destroying contaminants in all parts of the environment, which would leave land clean enough for a wide variety of uses, potentially including farming and public recreation. Two other cases were also analyzed that were more reflective of the contractual and legal requirements accounted for in the Base Case analysis.

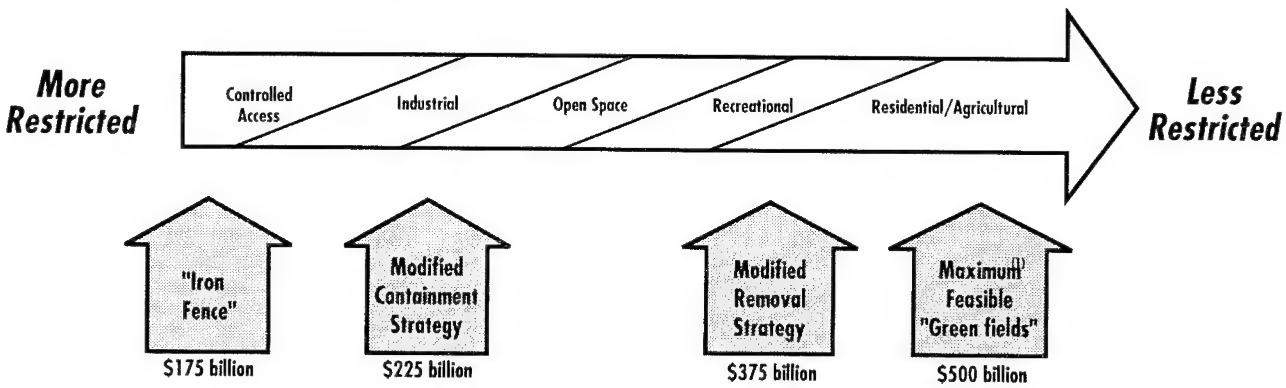
The life-cycle cost estimates for the range of land uses vary from approximately $175 billion to $500 billion depending on the level of cleanup assumed. This analysis indicates that future land-use determinations will have the single greatest impact on total program cost among the factors analyzed.

Each land-use case has its limitations. For example, containment rather than remediation is unrealistic across the Department of Energy complex because it would violate several existing cleanup compliance agreements. Also, in some cases, it is less costly to remediate contamination than to contain it. Establishing "green fields" at Department facilities nationwide is not realistic because it would preclude establishing any waste disposal areas, which must be located in restricted areas. Also, for certain contamination situations, technologies do not yet exist to remediate the environment to the level required for unrestricted use. For example, ground water beneath 150 square miles of the Hanford Site is contaminated with radioactive and chemical particles captured within a labyrinth of sediment and rock layers.

Residual Contamination Standards

Costs and schedules reported in the Base Case are based on each installation's best estimate of ultimate cleanup levels. The site-specific land use assumptions in the Base Case result in significant restrictions on future land-use at many of the sites. Variations in residual contamination standards have little impact on costs because containment, rather than the removal of contamination, is assumed to be used. The Department believes that more stringent cleanup standards will result in higher costs if more active remediation approaches are assumed. However, if less active remediation, such as containment is assumed, then little change in cost will occur

Figure 4. Conceptual Illustration of Land Use Continuum



(1) This scenario represents a modified "pure" Green fields case, which is not achievable at all sites with today's technology.

from more stringent residual contamination standards. More information must be collected, and analyses need to be conducted before costs can be quantified nationwide.

Program Funding and Schedule

Another set of analyses addressed the impacts of more or less available funding for the program. Assuming additional funding, the impacts of accelerating stabilization activities and early closure of sites were analyzed. Assuming reduced funding, the impacts of reducing the scope of remediation and waste management activities are also addressed. Highlights of the scheduling analysis are shown below.

- The life-cycle cost estimate for surveillance and maintenance could be reduced to approximately $500 million if pre-stabilization surveillance maintenance was reduced from 10 years (as in the Base Case) to 1 year. This is about 87 percent lower than the $4 billion in the Base Case. However, annual costs during the early years of the program would exceed the constant, or "flat," funding limit assumed for the Base Case.
- Almost $5 billion would be saved if the Department closed the Rocky Flats Site, Oak Ridge's K-25 Plant, and the Fernald Plant substantially earlier (20-40 years) than currently scheduled. However, annual costs would exceed flat funding limits for several years.
- If funding were significantly reduced beyond the year 2000, minimal action would require about $170 billion. This is about 27 percent lower than the Base Case through 2070. Minimal action would exclude environmental restoration, decontamination and dismantlement, and all treatment and disposal activities associated with future low-level, low-level mixed, and transuranic wastes. Annual surveillance and maintenance costs, however, would be as high as $500 million, compared with $50-$75 million projected in the Base Case.

Technology Development

Innovative technologies could make cleanup and other related activities more efficient and cost effective. More than 100 potential technology systems scheduled to be implemented by the year 2000 were screened based on the potential applicability to high-cost remediation projects. Of these, 15 were selected to evaluate potential cost savings.

Potential cost savings from implementing these new technologies range from $9 to $80 billion, depending on future land use strategies, and assuming the technologies could be implemented by 2010.

Waste Management Configurations

The Department currently is examining alternative configurations (centralized, regionalized, and decentralized) for waste management facilities. This involves deciding where in the country wastes will be stored, treated, or disposed.

Alternative configurations, ranging from decentralized to centralized approaches, could increase costs by $9 billion or decrease them by $5 billion from the Base Case, because of the potential for economies of scale in building and operating fewer facilities. There is substantial uncertainty about the exact benefits of these economies. More analysis should be available for next year's version of the report.

Next Steps

The purpose of the Baseline Report is to clearly articulate the potential life-cycle cost and schedule of the Department of Energy's Environmental Management program. The report represents numerous perspectives on the Base Case estimate, together with the analysis of the alternative cases, the range of policy, technical, and management decisions facing the program, and indeed, the Nation. After considering economic factors, productivity improvements, and alternative cases, the range of life-cycle costs for the Environmental Management program is seen to be substantial. Naturally, this range will narrow as the program matures. However, in the short term, the range of uncertainties highlights the need for a broad public debate both nationally and locally regarding the future of the Environmental Management program.

Many significant decisions must be made during the next several years that will affect the cost and direction of the Environmental Management program for years to come. This report provides a useful framework to analyze those decisions–the alternatives and their impacts. We expect next year's version of this report to change as a result of better information, additional analyses, and different assumptions resulting from stakeholder input. In addition, the compliance agreement and legal requirements underlying many of these estimates could be altered by regulators and Congress. The potential impacts of these changes can be better analyzed using an open process and an analytical tool such as this Baseline Report. Specifically, the next steps currently planned for next year's report are to:

- broaden the range of policy, technical, and management issues evaluated by the Baseline Report;
- improve the life-cycle cost and schedule estimates;
- use the Baseline Report tools to address ongoing program issues; and
- expand stakeholder involvement in the debate.

Contents

The 1995 Baseline Report consists of two volumes: Volume I – *The 1995 Baseline Environmental Management Report*, and Volume II – *Site Summaries for the 1995 Baseline Environmental Management Report.*

Volume I

Introduction (Chapter 1) sketches the basic framework of the report by providing background on the scope and technical complexity of the Department's environmental problems, a description of the scope of the

report mandated by the 1994 National Defense Authorization Act, and a description of the Environmental Management program in general.

Sources of Contamination and the Remedies (Chapter 2) describes in more detail both the sources of environmental contamination, the nuclear weapons production process and the various resulting waste types, and the responsibilities of the Environmental Management program.

The Base Case (Chapter 3) provides a detailed overview of the methods, data sources, and assumptions the Department used in developing a total life-cycle cost estimate.

Results (Chapter 4) describes the results of the Base Case analysis in constant 1995 dollars. It provides the projected life-cycle estimate for the major elements of the Environmental Management program—environmental restoration, waste management, nuclear material and facility stabilization, technology development, and program management. Costs are examined by State and site.

Alternative Cases (Chapter 5) illustrates how costs vary when assumptions are changed in four major areas: land use, scheduling, the pace of funding and activities, technology development, and waste management configurations.

Next Steps (Chapter 6) discusses how this report can be a more useful tool for national and local discussions on the future of this program.

Volume II: Site Summaries

Volume II presents the site-specific data used to generate the Department of Energy's 1995 Baseline Report. The site summaries provided in this volume give specific information about the activities and projected costs at each site as requested by the National Defense Authorization Act. The site summaries are organized alphabetically by State. Each summary provides a brief discussion of the site's past, current, and future missions followed by discussions of the projects and activities necessary to remediate the site. Costs and schedules are also provided, including milestones. The projects are divided into five activities: environmental restoration; waste management; nuclear material and facility stabilization; landlord activities; and program management.

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1.0 Introduction

The Department of Energy's Office of Environmental Management, established in 1989, manages the largest environmental stewardship program in the world—with over 140 sites and facilities in over 30 States and territories. The primary focus of the program is to reduce health and safety risks from radioactive waste and environmental contamination resulting from the development, production, and testing of nuclear weapons during the Cold War. Past efforts have put the estimated cost of the program at several hundred billion dollars over several decades. In an attempt to better understand the magnitude of this effort, Congress required the Secretary of Energy to submit a Baseline Environmental Management Report by March 31, 1995, with annual updates to follow.

The 1995 Baseline Environmental Management Report (Baseline Report) provides a life-cycle cost estimate, tentative schedules, and projected activities necessary to complete the Environmental Management program. In doing so it represents the Department's most comprehensive effort to date to develop a clearer picture of the "Cold War Mortgage."

1.1 The Cold War Mortgage

In the United States, World War II and the Cold War led to the development of a vast network of industrial facilities for the research, production, and testing of nuclear weapons, known as the "nuclear weapons complex." It includes thousands of large industrial buildings such as nuclear reactors, chemical processing buildings, metal machining plants, and maintenance facilities. Over the last 50 years, this enterprise manufactured tens of thousands of nuclear warheads and detonated more than a thousand. The Department of Energy, the Federal agency now responsible for managing the nuclear weapons complex, manages more than 120 million square feet of buildings and 2.3 million acres of land—an area larger than Delaware and Rhode Island combined.

In addition to creating an arsenal of nuclear weapons, the complex left an unprecedented environmental legacy. Because of the priority on weapons production, the treatment and storage of radioactive and chemical waste was handled in a way that eventually led to contamination of soils, surface water, and ground water in and around facilities. For example, at the Hanford Site in Washington State, radioactive wastes have leaked from several of the one-million-gallon underground storage tanks. As a result of the revelations by the news media and non-governmental organizations, as well as studies conducted by the Department of Energy during the last 10 years, this legacy is generally well-known.

The nuclear weapons complex essentially shut down production operations in the late 1980's, leaving not only the legacy of thousands of contaminated areas and buildings, but huge volumes of "backlog" wastes awaiting treatment and a large amount of special nuclear materials still in the "pipeline" of the production facilities. For example, over 100 million gallons of high-level radioactive waste are stored in about 250 tanks at the Hanford Site in Washington, the Savannah River Site in South Carolina, and the Idaho National Engineering Laboratory in Idaho. About 1,300 cubic meters of highly radioactive spent nuclear fuel, some

of which is corroding, remains in continuously monitored storage. Approximately 26 tons of plutonium scraps and residues—no longer needed for nuclear weapons production—must be stabilized, safeguarded, and dispositioned.

The "Cold War Mortgage," then, can be thought of as the cost and effort associated with addressing these issues. This expense was deferred in the heat of the nuclear arms race. Paying the mortgage will take decades and enormous resources.

1.2 What Does the Nation Want to Buy?

The future course of the Environmental Management program will depend on a number of fundamental technical and policy choices. Most of these choices have not yet been made, although preliminary decisions have been made in many cases. Ultimately, meaningful decisions can only be made through adequate stakeholder input. The cost and environmental implications of alternative choices can be profound.

Some choices are more ethical than technical in nature. For example, what obligation does the present generation have to future generations regarding future land use? Many contaminated sites and facilities could be restored to a pristine condition, suitable for any desired use; they also could be restored to a point where they pose no health risks to surrounding communities but are essentially surrounded by fences and left in place. The former would obviously have a higher cost, but, depending on one's perspective, it may or may not be worth it. Resolving such issues will depend on what the Nation wants to buy.

Other key questions that affect the cost of the program include the following:

- What level of residual contamination should be allowed to remain after cleanup?
- Should projects with high safekeeping costs (i.e., high storage costs pending ultimate disposition of materials) be given priority over certain low-risk cleanup activities? In other words, how should cost affect priorities?
- Should cleanup and waste management proceed with existing technologies, or is it prudent, in some cases, to wait for the development of improved technologies? What criteria should guide decisions on this issue?
- Should activities be carried out in decentralized, regional, or centralized facilities? How are issues of equity among states factored into configuration decisions?

The most effective way to resolve these issues is to engage in a broad-based national and local debate to assess the costs, risks, and other tradeoffs associated with different approaches. The 1995 Baseline Report lays the foundation for this debate. It describes where the Environmental Management program is headed, according to current assumptions, and illustrates potential impacts if these assumptions vary. Additionally, the report will establish a more-disciplined inventory of the problems and the potential liabilities that can be used as a management tool.

1.3 What the Baseline Report Covers

The 1995 Baseline Report was prepared in response to a congressional mandate made first in the 1994 National Defense Authorization Act (Appendix A). Congress directed the Department to

- estimate the total cost of the Environmental Management program;
- describe each project or activity at each site;
- describe the environmental problem addressed by each project or activity;
- specify the proposed remedy or solution to the problem, if known;
- estimate the cost of completing each project or activity (in 5-year increments where appropriate); and
- provide a schedule and estimated completion date for each project or activity (with progress milestones for every 5-year increment).

The Baseline Report addresses the requirements of the 1994 National Defense Authorization Act in Volume I in Chapter 4, Results, and Chapter 5, Alternative Cases. More specific requirements of the Act, such as a description of and costs for projects and activities at the installation level, are answered in the Site Summaries, Volume II, of the Baseline Report.

Working from these congressional requirements, the Department prepared a "Base Case" cost estimate. The Base Case was constructed with data provided primarily by the field offices and sites. The cost and schedules were based on meeting existing compliance agreements, including milestones for as long as they were established. Information included costs and schedule estimates for environmental restoration; nuclear material and facility stabilization; and waste treatment, storage, and disposal activities at each installation. It also included costs for related activities such as landlord responsibilities, program management, and legally prescribed grants for participation and oversight by Tribes and regulatory agencies.

For the purpose of this report, the Environmental Management program was considered "complete" when all sites had been remediated and when waste generated from previous missions and remediation and stabilization activities was projected to be safely disposed. Following completion of these activities, annual costs were assessed for surveillance and monitoring, where appropriate, to ensure adequate protection of human health and the environment at all closed sites. Finally, annual costs were estimated for managing waste projected to be generated in the future from Departmental activities such as energy, basic science, and weapons research.

The Base Case estimate was built on a broad range of assumptions regarding the outcomes of various decisionmaking processes that will determine the ultimate disposition of Department of Energy facilities and installations and, hence, the scope and pace of the Environmental Management program. Because of the many unanswered questions in this regard, the Department also examined how Base Case costs might vary under differing sets of assumptions. Four key areas most likely to affect total costs were analyzed: (1) possible variation in future land use; (2) activity prioritization and scheduling; (3) technology development; and (4) configuration of treatment, storage, and disposal facilities.

1.4 Estimates, Not Decisions

Many broad assumptions were required to make it possible to estimate the long-range costs and schedules to complete the Environmental Management program. Indeed, preliminary answers had to be posed regarding future land use; cleanup level; and pace, priority, and configuration of activities even to define the Base Case. In addition to the uncertainty of long-term programmatic and institutional issues, significant uncertainties stem from limitations in existing data. For example, of the approximately 10,500 potential "release sites" (sources of contamination), only one-fourth are fully characterized, and the future missions of many installations are ill-defined.

Previous Cost Estimates

The Federal Government last estimated the total cost of environmental liabilities at Department of Energy facilities in 1988 before the end of the Cold War, when the renovation and indefinite operation of the existing nuclear weapons complex was being planned. These cost estimates primarily assessed what was needed to bring installations into compliance with environmental regulations to allow continued weapons production. For example, estimates focused on permitting installations and operation of air and water monitoring systems, with limited short-term corrective action at active sites. Little emphasis was placed on more expensive activities such as remedial action at inactive sites. These estimates ranged from $100 to $300 billion for total program cost. Even higher estimates were produced by speculative extrapolation without the benefit of the type of field data on which this report is based.

The Baseline Report is dramatically different—both the results and the methodology—from past estimates for a number of reasons. First, this Base Case estimate in this report is based on a "bottom up" approach using large amounts of data and assumptions collected from field offices, rather than centralized estimating processes, which were used in previous estimates. Second, this report does not attempt to provide cost estimates for cleanup activities that are not technically feasible using existing technologies. Such estimates, which were included in some previous estimates, do not make sense because complete cleanup using existing technologies cannot be attained at any price for certain contamination situations such as nuclear weapons test residues or large areas of contaminated ground water and river system sediments. Third, the activities for which estimates are provided in this report reflect the Department's significantly reduced nuclear weapons production requirements. Finally, the Baseline Report also reflects a greater understanding of the nature and extent of contamination, as well as broader program support responsibilities than assumed for previous estimates. As a result of these differences, this Baseline Report is not comparable in scope and is substantially improved in the level of detail and integration over past estimates.

The development of the Base Case and alternative cases, which are based on tentative assumptions and limited data, should not be interpreted as shaping Departmental policy, budget requests, or long-term plans. Decisions can only be reached through developing and sustaining national and local debate involving the people whose lives these decisions will affect. Providing a framework for such discussion is a key purpose of *The 1995 Baseline Environmental Management Report.*

1.5 Preview of the Report

This report consists of two volumes: Volume I, *The 1995 Baseline Environmental Management Report*, and Volume II, *Site Summaries for the 1995 Baseline Environmental Management Report.*

Volume I begins with a summary of the entire report followed by an introduction (Chapter 1) that sketches the basic framework for the report—the Cold War mortgage and the Environmental Management program—and briefly characterizes the report itself. Chapter 2 describes in more detail both the sources of environmental contamination and the remedy—the Environmental Management program. It establishes the background necessary for understanding Chapter 3, the Base Case, and Chapter 4, the results of the cost-and-schedule estimating exercise. Alternative cases to the Base Case and cost-and-schedule estimates are presented in Chapter 5. The next steps for the Environmental Management program are discussed in Chapter 6. Volume I also contains a bibliography, glossary, and several appendixes. Appendix A reprints the portion of the National Defense Authorization Act for FY 1994 pertinent to this Baseline Report. The other appendixes present information pertinent to the cost-and-schedule analysis and list reading rooms where this report and background materials reside.

Volume II contains summaries for each site included in the baseline estimate. These summaries start with the past, present, and future missions of current facilities at the site; review existing contamination problems at each site and remedial actions under way or planned; and describe activities or plans for facility stabilization and waste management. Landlord functions, where pertinent, and program management are also included. Each summary includes tabulated cost estimates, funding data, and milestones lists.

2.0 Sources of Contamination and the Remedies

Production of nuclear weapons in the United States required the use of a vast array of facilities—mines, laboratories, nuclear reactors, chemical plants, machine shops, and test sites. At all sites where these activities took place, some environmental contamination occurred. In some instances, the contamination is contained, posing no immediate risk to people and the environment. In others, however, the contamination is extensive enough to have polluted not only the surrounding soils but also the underlying ground water. Most waste generated by the Department of Energy is radioactive, and therefore, cannot be eliminated—it can only be contained in a safe manner while its radioactivity diminishes.

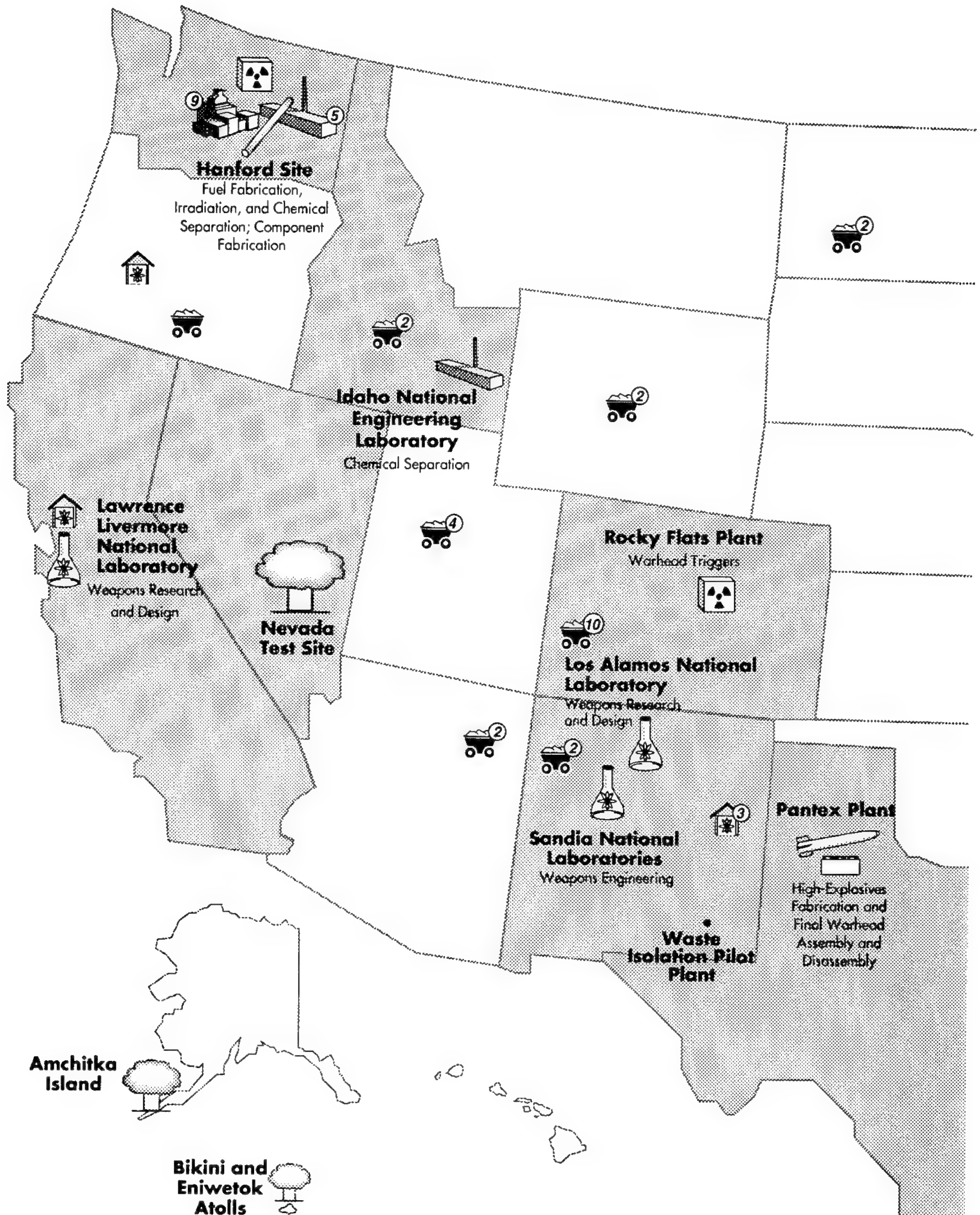
Although, by far, the major focus of the Environmental Management program is to address the environmental legacy of nuclear weapons production activities, wastes come from other sources as well. Nonweapons legacy wastes include those wastes associated with managing past activities, such as energy research, basic science, and the Three Mile Island nuclear power plant accident. Newly generated radioactive wastes from ongoing research activities within other programs at the Department of Energy are also managed by the Environmental Management program. Environmental Management will also continue to be responsible for managing applicable wastes generated by the U.S. Navy's nuclear reactors. Finally, some wastes will be generated from future weapons dismantlement or maintenance activities.

This chapter describes the primary sources of contamination for which Environmental Management has responsibility and the types of activities required to address the concern (e.g., the process of remediation and key waste management activities). Where appropriate, specific sites or facilities are named as examples. Readers who are interested in more-detailed information about the production of nuclear weapons will find the processes described further in Appendix B. Readers who are interested in more-detailed information about specific sites—or specific States—will find them described in Volume II.

2.1 Contamination from Nuclear Weapons Production

At the core of the weapons-manufacturing process was the production of three materials—highly enriched uranium, plutonium, and tritium. Production of these nuclear materials required the most complicated facilities in the weapons complex and was responsible for most of the environmental legacy of the Cold War. Figure 2.1 shows where various weapons production facilities are located and which step in the production process they represent. The following discussion briefly describes the process of producing nuclear weapons, including the environmental legacy of each process.

Uranium Mining and Milling—The United States mined about 60 million tons of ore to produce uranium for nuclear weapons production. Mining and milling pro-



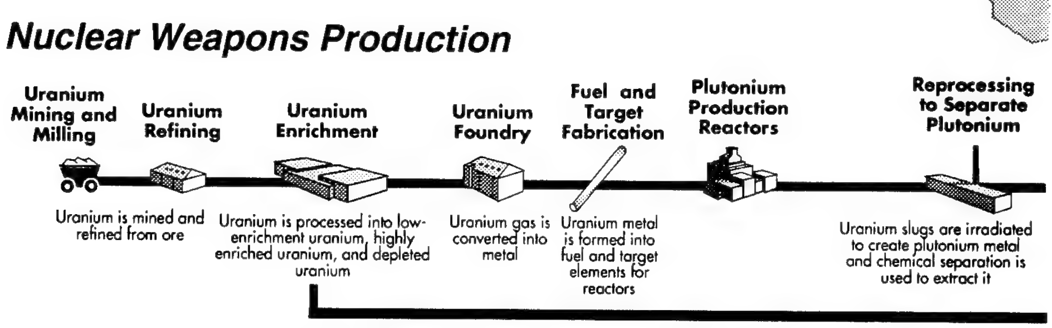
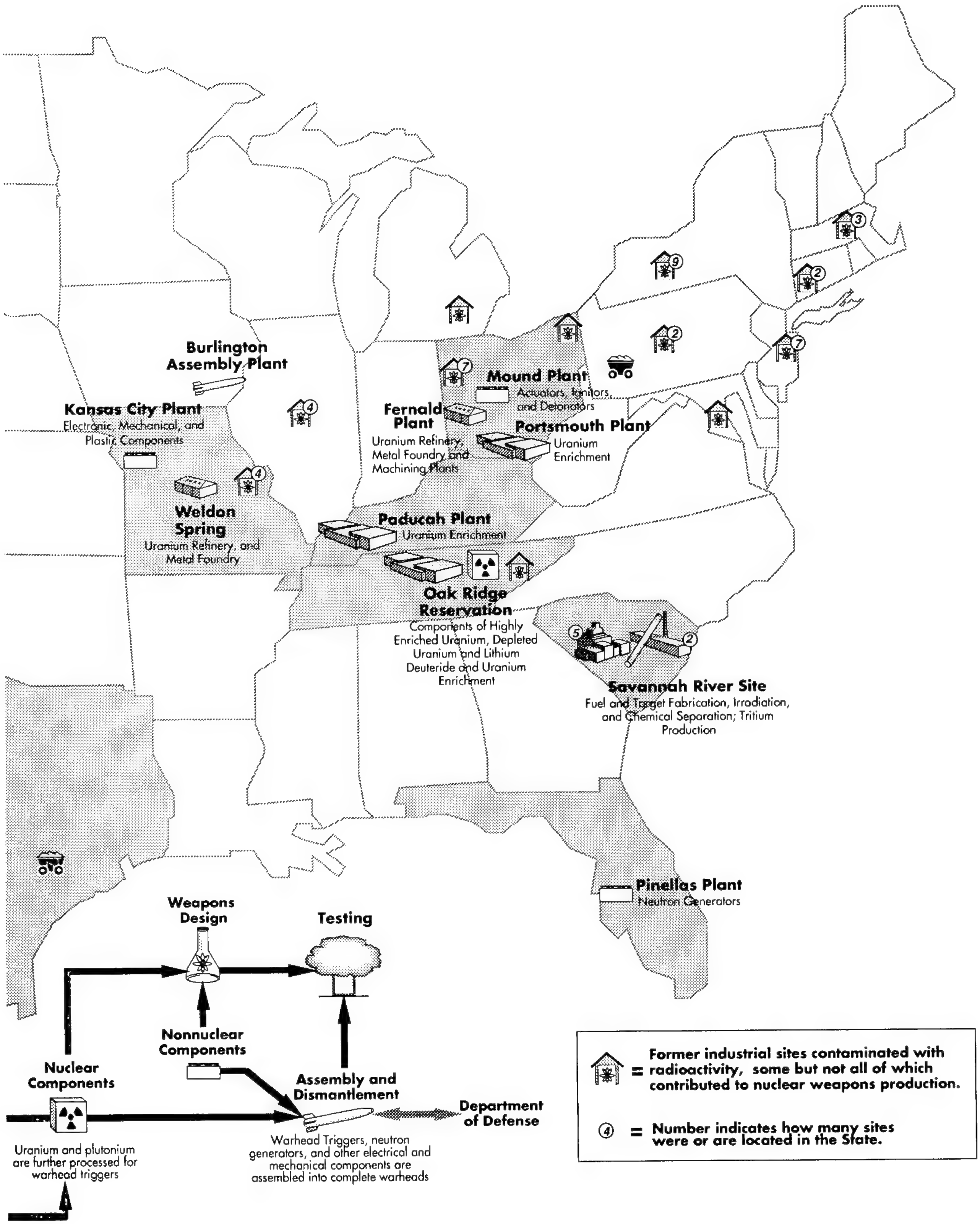


Figure 2.1. Locations of Nuclear Weapons Production and Assembly Activities



Burlington Assembly Plant
Kansas City Plant
Electronic, Mechanical, and Plastic Components
Weldon Spring
Uranium Refinery, and Metal Foundry
Fernald Plant
Uranium Refinery, Metal Foundry and Machining Plants
Mound Plant
Actuators, Ignitors, and Detonators
Portsmouth Plant
Uranium Enrichment
Paducah Plant
Uranium Enrichment
Oak Ridge Reservation
Components of Highly Enriched Uranium, Depleted Uranium and Lithium Deuteride and Uranium Enrichment
Savannah River Site
Fuel and Target Fabrication, Irradiation, and Chemical Separation; Tritium Production
Pinellas Plant
Neutron Generators
Weapons Design
Testing
Nonnuclear Components
Nuclear Components
Assembly and Dismantlement
Department of Defense
Uranium and plutonium are further processed for warhead triggers
Warhead Triggers, neutron generators, and other electrical and mechanical components are assembled into complete warheads
= Former industrial sites contaminated with radioactivity, some but not all of which contributed to nuclear weapons production.
④ = Number indicates how many sites were or are located in the State.

duced large volumes of a sand-like byproduct called "mill tailings," which contain both toxic heavy metals and radioactive radium and thorium. Although there is a large volume of this material, it represents only a small fraction of the total radioactivity managed by the Environmental Management program.

Uranium Enrichment—To make highly enriched uranium, enrichment plants removed and separated uranium-235 from uranium-238. Enrichment plant operations produced large volumes of enriched uranium and environmental contamination with radioactive materials, solvents, polychlorinated biphenyls (PCBs), heavy metals, and other toxic substances.

Fuel and Target Fabrication—The conversion of uranium hexafluoride gas into metal. The main types of environmental legacies from these operations are unintended releases of uranium dust, landfills contaminated with chemicals, and contaminated facilities.

Reactor Irradiation—Uranium targets were irradiated in production reactors to produce plutonium. Their main environmental legacy is highly radioactive spent fuel, and contaminated facilities.

Chemical Separations—The chemical separation of fission products from uranium and plutonium generated more than 100 million gallons of highly radioactive and hazardous chemical waste, some of which was discharged directly into the ground. Waste from reprocessing contains the vast majority of the total radioactivity managed by the Environmental Management program, much of it emitted from long-lived radioactive elements that could pose hazards for tens of thousands of years. Chemical separations also left a legacy of contaminated facilities.

Fabrication of Weapons Components—Plutonium was machined into warhead components. The weapons laboratories also used plutonium to make and test prototype designs for weapons. Waste from this process is mostly plutonium-contaminated (transuranic) waste.

Weapons Assembly and Maintenance—Factories contributed nonnuclear components for the final assembly of nuclear weapons. The environmental legacy includes soil contaminated with high-explosive waste, fuel and oil leaks, and solvents.

Research, Development, and Testing—More than 1,000 nuclear devices were exploded in atmospheric, underwater, and underground tests. The environmental legacy includes hundreds of highly radioactive underground craters and soils and debris contaminated with low-level waste. Testing nonnuclear components left contamination with high-explosive materials and other chemicals.

For a more detailed discussion, refer to Appendix B, *The Nuclear Weapons Production Process*.

2.2 Contamination from Other Sources

Although the environmental costs of nuclear weapons production are substantial, the Environmental Management program also addresses a legacy of waste from nonweapons production as well as wastes generated by ongoing activities.

The nonweapons legacy wastes are those wastes associated with cleaning up waste generated from past activities, such as energy research, basic science, the

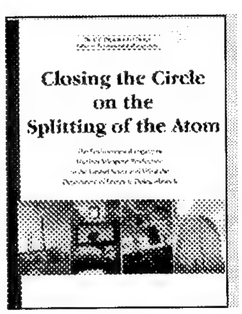
Three Mile Island nuclear plant accident. For example, Brookhaven National Laboratory's environmental restoration activities are focused on remediation of contamination of soil, surface water, and possibly ground water resulting from research and development work by the U.S. Army and the Department of Energy since 1947. At the West Valley Demonstration Project, New York, the Environmental Management program manages approximately 600,000 gallons of high-level waste from the previous reprocessing of spent nuclear fuel, primarily from commercial nuclear power plants. The Environmental Management program is responsible for demonstrating the technology for solidifying high-level waste and cleaning up the facilities that are used. At the Princeton Plasma Physics Laboratory, New Jersey, which carried out nuclear fusion research and development for the Department for more than 40 years, contamination sources include former wastewater treatment plant facilities, a cooling tower and its adjacent soils, the chromate reduction pits, and a hazardous waste accumulation area.

The Environmental Management program also manages waste from other ongoing programs within the Department of Energy such as the Office of Energy Research and the Office of Nuclear Energy. For the purpose of this Baseline Report, it is assumed most of these sites will continue operations.

2.3 The Environmental Management Program

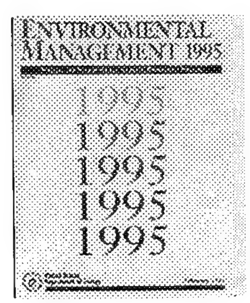
The Office of Environmental Management was created in 1989 to help address the environmental legacy of nuclear weapons production and other sources such as nuclear research programs. The program encompasses remediation of the environment that has been contaminated with radioactive materials as well as hazardous chemicals. The program uses safe and practical strategies for dealing with a variety of radioactive and toxic wastes. It also entails the stabilization and safekeeping of hundreds of facilities that have no similar counterparts in any other segment of society, military or civilian. Finally, it requires the management of special nuclear materials such as plutonium and highly enriched uranium. The scope of activities

For a comprehensive background of the Environmental Management program and a description of program accomplishments, see the following recently published reports:



Closing the Circle on the Splitting of the Atom (January 1995) describes existing environmental, safety, and health problems throughout the nuclear weapons complex, and what the Department of Energy is doing to remedy the problems.

Environmental Management 1995 (February 1995) is the Office of Environmental Management's annual report on the program's progress. It assesses the program's performance in 1994 compared with 1993.



To obtain copies of these reports, or for more information on the Environmental Management program, please contact the Center for Environmental Management Information at 1-800-7-EM-DATA.

within the Environmental Management program has no technical precedent, making it difficult to rely on experience from other endeavors.

Activities that encompass the Environmental Management program are broken into four major functional areas: (1) environmental restoration; (2) waste management; (3) nuclear material and facility stabilization; and (4) technology development. Landlord functions represent a fifth area of additional cross-cutting support activities. Figure 2.2 graphically shows the scope of the Environmental Management program and key interrelationships of the four major areas. Primary among these is waste management, which involves safe treatment, storage, and disposal of existing waste and waste still to be generated. Environmental restoration activities address remediation of contaminated soil and water as well as decommissioning of contaminated surplus facilities. Facility stabilization involves collecting and consolidating dangerous nuclear materials in surplus facilities before dismantlement. Technology development refers to a variety of applied research activities to develop more effective and less expensive remedies to address the environmental and safety problems of the Environmental Management program. The following subsections describe each major area and key relationships among them.

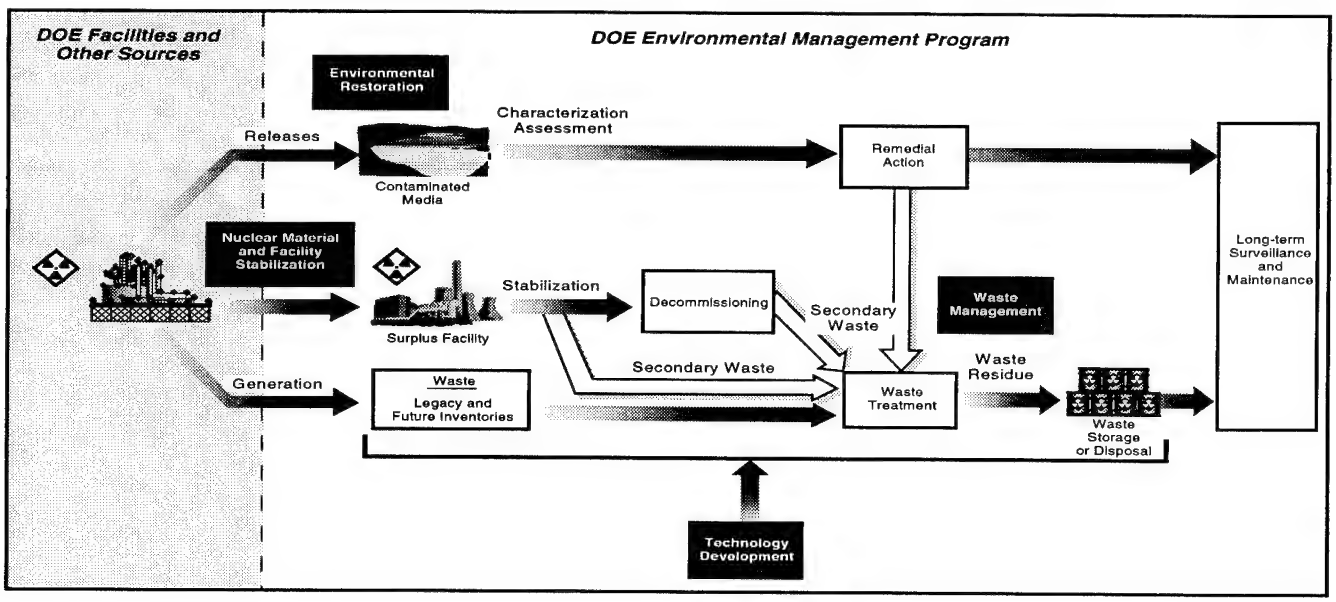


Figure 2.2. Overview of Department of Energy Environmental Management Activities

2.3.1 Environmental Restoration

Environmental Restoration Mission

Environmental restoration is what is usually described as "cleanup." It encompasses a wide range of activities such as stabilizing contaminated soil; treating ground water; decommissioning process buildings, including nuclear reactors and chemical separations plants; and exhuming buried drums of waste. The extent to which a site is "cleaned up" will depend largely on assumptions regarding future land use. For most sites, the process of determining future site use has only just begun.

Environmental Restoration Activities

Site characterization is the process of determining the contaminants at a release site. The process generally includes the review of historical records (e.g., past production reports, drawings, audit reports), walk-downs to conduct visual inspections and limited testing with hand-held detectors, and more extensive sampling of all potentially contaminated media, such as ground water, soil, and building surfaces. The evaluation of media samples for types of contamination is followed by determination of the associated risks of contamination to the environment, the risk of cleanup, and the proper approach for decontamination or remediation.

Site remediation follows careful assessment and characterization and may include actions which actually remove contaminants or merely stabilize the contaminants to prohibit migration through the air, soil, or ground water. Removal techniques may include exhumation of soils, soil washing, bioremediation (using organisms which eat contaminants in soils or ground water), or pumping and filtering ground water. Stabilization or containment techniques include capping of soil or buried waste sites, in-situ vitrification (heating soil to the melting point to make "glass" and trap contaminants), or pumping and reinjecting ground water to stop the spread of contaminants.

Decommissioning activities involve the decontamination and safe disposition of surplus facilities that have been deactivated. The safe disposition may include reuse of a completely decontaminated building, demolition of the building with rubble removed from the site, or entombment which might involve collapsing the structure into its basement level and capping the contaminated rubble in place. The contents of these surplus facilities are primarily reactors, hot cells, processing plants, storage tanks, research facilities, and other structures where releases or spills have occurred.

Long-term surveillance and monitoring physically demonstrate that contamination has been successfully removed, contained or reduced such that the level of risk associated with the waste stream is no longer considered a threat to human health or the environment. Also included are maintenance activities where containment remediation approaches have been implemented, such as capping of buried waste and entombment of buildings. In the instance of ground-water contamination, pumping and treating involve continued operations for a long period of time.

Environmental Cleanup: The Regulatory Process

The general process to reach decisions concerning cleanup actions is laid out by statutes including the Comprehensive Environmental Response, Compensation and Liability Act; the Resource Conservation and Recovery Act; and the National Environmental Policy Act. The process is generally implemented at specific sites through agreements among the Department of Energy, the U.S. Environmental Protection Agency, and frequently the host State. The process can be described as follows:

First, a site or a portion of a site is "characterized" to identify contaminants, determine the extent of contamination, and assess potential threats to public health and the environment. If significant contamination is indicated, and limited action will result in mitigation of risk, an expedited response action or interim action may be conducted as a means to quickly address the problem. To date, over 500 such expedited actions have been completed, avoiding larger contamination problems that surely would have resulted from delay.

Upon completion of characterization, a detailed analysis is performed to quantify risk and evaluate remedial alternatives. The analysis is followed by a formal decision process including public meetings and a formal comment period.

If the results of the analysis indicate that a potential release site (which may be organized into an "operable unit" or "waste unit" with other related release sites) is not a threat to health and the environment or that an interim action adequately remediated the contamination, a recommendation of no further action is made to the regulators. If, however, a threat is deemed to be present, the appropriate remedial action is identified, and a recommendation is submitted for formal approval.

In deciding on the proper course of action, it is important to ensure that the cleanup action itself will not pose a greater hazard to workers and the general public than not disturbing the contaminated area. It is also necessary to determine how much waste will be generated in the cleanup and make provisions for its storage, treatment, and disposal. If actual cleanup is not practical, or not required because of decisions regarding future land use, steps may be taken to stop or slow the spread of contamination. The action depends on the contaminants and the medium (soil or water) in which they are found. Contaminants such as hazardous chemicals or fuel oil can be effectively removed from the media and destroyed, but heavy metals and radioactive materials cannot be destroyed, even when it is possible to remove them from the media. Over time—from days to tens of thousands of years—the radioactivity will decay naturally. Meanwhile, radioactive and heavy metal-contaminated soils or radioactive waste must be contained, stabilized, or moved to a safer place. Future costs associated with contamination that has not been fully remediated or is stabilized in place result from continuous monitoring and maintenance of containment structures.

To date, the Department has obtained decisions and completed 119 remedial action projects with another 111 projects under way. These projects have included cleanup of contaminated soils, building of ground water treatment facilities, and retrieval of buried waste. The Department is positioned to do even more cleanup in the near term as many characterization activities are complete or nearing completion, and many formal cleanup decisions will be made over the next few years.

The Decommissioning Process

The decommissioning of surplus facilities involves a decision-making process similar to that for environmental cleanup—characterization followed by detailed analysis of alternatives and formal remedy selection. This process is generally governed by the stipulations of the National Environmental Policy Act, although some future decommissioning may be required and executed under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act.

Decommissioning activities are generally lower priority than soil, buried waste, or ground-water contamination sites because their contamination is contained within buildings, but the deteriorating condition of buildings poses substantial hazard to surveillance and decommissioning workers, and the recurring costs associated with maintaining surplus facilities absorbs resources that could be better spent on remediation. A balance between these priorities must be struck to maximize future program progress.

The decommissioning program is in its infancy. Of the 3,500 contaminated facilities that are surplus or projected to be surplus within the next 10 years, 100 facilities have been decommissioned to date. In spite of its modest beginnings, the program has placed a priority on minimizing secondary waste and has recycled 16 million pounds of scrap metal from dismantled facilities and equipment.

2.3.2 Waste Management

The Waste Management Mission

The waste management mission of the Environmental Management program is to treat, store, and dispose of wastes and to manage spent nuclear fuel generated during past and future Department of Energy activities. Waste management involves managing large volumes of "backlog" wastes existing now at various facilities throughout the United States. At the end of 1993, approximately 1 million cubic meters of radioactive waste were stored in facilities at various Department of Energy installations. Additional wastes are expected from environmental restoration and facility stabilization activities as well as from other ongoing activities within the Department of Energy.

Based on their physical and chemical characteristics, wastes are divided into a variety of categories including high-level radioactive waste, transuranic waste, low-level radioactive waste, low-level mixed waste, hazardous chemical waste, and sanitary waste. Each type of waste requires a different strategy for management, as each has specific requirements for treatment, storage, and disposal. Spent nuclear fuel, although not classified as waste, is managed by the Environmental Management program and also requires a unique management strategy. The box on the following page provides additional information on various waste types and spent nuclear fuel.

Environmental restoration and facility stabilization will generate wastes that will consist primarily of contaminated soils, rubble, debris, residues, chemicals, and equipment. Although most of wastes are expected to be low-level, low-level mixed waste, or hazardous waste, substantial volumes of transuranic waste from exhumation of buried wastes are included in this analysis.

Definitions of Waste Types and Spent Nuclear Fuel

High-level waste resulted from the chemical processing of spent nuclear fuel to recover special nuclear materials. High-level waste is stored largely as a liquid or sludge, with some waste in the form of calcine. High-level wastes contain hazardous constituents regulated under Subtitle C of the Resource Conservation and Recovery Act.

Spent nuclear fuel includes all nuclear fuel generated by Department of Energy production reactors, university and government research reactors, foreign research reactors that use fuel of U.S. origin, and naval nuclear propulsion reactors (including training, prototype, and service reactors). Except for a few special cases (e.g., Three Mile Island), the Environmental Management program is not responsible for managing spent nuclear fuel from commercial reactors.

Transuranic waste includes wastes with over 100 nanocuries per gram of plutonium or other long-lived radionuclides that are heavier than uranium. This waste does not generally require the remote handling needed for high-level waste and spent nuclear fuel but contains radionuclides that remain radioactive for thousands of years. Most transuranic waste was generated during the production of nuclear weapons and contains hazardous constituents regulated under Subtitle C of the Resource Conservation and Recovery Act.

Low-level waste includes all radioactive waste not classified as high-level waste, mixed waste, and transuranic waste. Low-level waste also excludes uranium and thorium tailings. These wastes are subject to provisions of the Atomic Energy Act.

Low-level mixed waste is low-level waste that also is contaminated with hazardous constituents regulated under Subtitle C of the Resource Conservation Recovery Act.

Hazardous waste is waste that is regulated under Subtitle C of the Resource Conservation Recovery Act. It contains hazardous constituents but no radionuclides. Hazardous waste is generated at most of Department of Energy installations in a variety of quantities and forms (e.g., laboratory solutions, acids, bases, and degreasing agents).

Sanitary waste includes solid sanitary waste (e.g., garbage, rubble, or debris) regulated under Subtitle D of the Resource Conservation Recovery Act and liquid sanitary waste regulated under the Clean Water Act.

Waste Management Strategies

The management strategy for each type of waste often depends on consent orders and Agreements-in-Principle the Department of Energy has entered into with host States and the U.S. Environmental Protection Agency largely in accordance with requirements of the Resource Conservation and Recovery Act. For example, for mixed waste (which includes high-level waste, most transuranic waste, and low-level waste with hazardous constituents), the Department of Energy is complying with requirements of the Federal Facility Compliance Act. The Act requires the Department to develop and submit Site Treatment Plans to the U.S. Environmental Protection Agency or State regulators for approval. These plans describe the treatment of mixed waste. Forty-one sites in 21 States currently are developing Site Treatment Plans. To ensure the plans are acceptable, the Department began nego-

tiations with the affected States, facilitated by the National Governors' Association. This report incorporates assumptions (e.g., where major volumes of wastes will be treated) from this process. Approval of Site Treatment Plans by the U.S. Environmental Protection Agency or the affected States is required by October 1995.

The following text describes current assumptions regarding treatment, storage, and disposal facilities for the different waste types.

High-level waste is stored in large tanks at the Savannah River Site, Idaho National Engineering Laboratory, Hanford Site, and West Valley Demonstration Project. Because the Department has ended special nuclear materials production operations and is phasing out chemical reprocessing of fuel, large volumes of high-level waste are not expected to be generated in the future. Small amounts of high-level waste are expected to be generated during nuclear material and facility stabilization activities.

Regulations require high-level waste to be converted to durable, stable solid form for disposal. The Department is developing safe, reliable, and cost-effective methods for the characterization, retrieval, pretreatment, and final disposition of these wastes. The preferred treatment for most high-level waste is mixing solid waste with glass frit and vitrifying it to borosilicate glass that solidifies inside steel canisters. Some high-level waste may be converted to a ceramic form. The steel canisters will be stored in aboveground storage facilities until disposal. Vitrification facilities at Savannah River and West Valley are about to begin operation.

Disposal for high-level waste currently is not available. It must await the opening of a geologic repository that is yet to be built and for which a site, though identified, has not yet been approved. The repository, to be developed by the Department's Office of Civilian Radioactive Waste Management, is not expected to be available to accept Department of Energy waste until the year 2016 at the earliest.

Spent nuclear fuel is primarily in solid form as metal-clad rods, that require no treatment for near-term storage. Broken or punctured rods must be overpacked to contain the radioactive material. Most spent fuel is stored in water pools at the Hanford Site, Idaho National Engineering Laboratory, Savannah River Site, and Oak Ridge Reservation; this traditional method of storage requires constant maintenance, such as water purification to prevent corrosion. More efficient storage will be provided in dry aboveground facilities the Department plans to develop. These facilities will use specially engineered storage canisters. Some treatment of spent fuel may be required before final disposal, but it is premature to make decisions in this regard until waste acceptance criteria for the repository are developed. Alternatives for treatment of spent nuclear fuel are presently being examined.

Spent fuel requires permanent isolation in a geologic repository. Current plans call for emplacing it with high-level waste in a repository.

Transuranic waste is stored in a retrievable manner (mostly at the Idaho National Engineering Laboratory, but also at the Savannah River Site, Los Alamos National Laboratory, and the Hanford Site) pending the opening of a geologic repository. Storage facilities are being upgraded or constructed to comply with the requirements under Subtitle C of the Resource Conservation and Recovery Act. Before 1970, these wastes were buried in shallow trenches, mostly in Idaho and Hanford. The environmental restoration program is determining future actions at the burial sites under the Comprehensive Environmental Resource Conservation and Liability Act process.

The Department intends to dispose of the stored backlog and newly generated transuranic waste in a deep underground geologic repository. During the 1980's, the Department excavated an underground salt layer in southern New Mexico, referred to as the Waste Isolation Pilot Plant. The Department expects to use this facility to dispose of transuranic waste, if the Department determines that it is suitable for disposal and permission is granted by the U.S. Environmental Protection Agency and the State of New Mexico Environment Department under the provisions of the Waste Isolation Pilot Plant Land Withdrawal Act. The Department is now completing the prerequisites to arrive at this decision, which is expected to be made in 1998.

Before being shipped to the Waste Isolation Pilot Plant, all transuranic waste currently in storage will have to meet the waste acceptance criteria for the Waste Isolation Pilot Plant and be certified to that effect. Many containers in which the waste is stored (steel drums or boxes) will need repackaging to meet transportation requirements. In addition, some treatment may be required to meet waste acceptance criteria, which have not been finalized and will not be available until the U.S. Environmental Protection Agency and the State of New Mexico complete their regulatory reviews.

Low-level waste ranges from low-activity waste that can be disposed of by shallow land disposal techniques to high-activity waste that requires disposal techniques providing greater confinement. Low-level waste currently is generated at more than 30 different installations and disposed of at the Savannah River Site, the Oak Ridge Reservation, the Idaho National Engineering Laboratory, the Nevada Test Site, the Los Alamos National Laboratory, and the Hanford Site.

Low-level waste generally undergoes minimum treatment—volume reduction, solidification of liquids, and packaging to transport and dispose of the material. Similarly, waste storage is kept to a minimum because disposal operations are ongoing at six installations.

Because low-level waste may have high or low levels of radioactivity, disposal methods vary. The disposal method (e.g., shallow land burial or engineered vaults) used at a given site depends on the geologic conditions and types of radioactive material to be disposed.

Waste Minimization and Pollution Prevention

The Department of Energy instituted a waste minimization program at all its facilities. The Environmental Management program administers the program. Waste minimization and pollution prevention means preventing or reducing the generation of pollutants, contaminants, hazardous substances, or wastes at the source or reducing the amount of waste requiring treatment, storage, and disposal through recycling. These objectives can be achieved by administrative and procedural changes, design features incorporated into new facilities, and design modifications in existing facilities, increased use of existing technologies, and expanded technology development efforts. The program has set a goal to reduce by 50 percent the total release to the environment of toxic chemicals generated through routine operations by December 31, 1999. For example, wastewater treatment has been improved by replacing antiquated equipment and processes and site-wide programs have begun to recycle materials such as aluminum, paper, lead, oil, tires, and excess chemicals.

Although not included in this analysis, the department is responsible for disposing of Greater Than Class C low-level waste from Nuclear Regulatory Commission-licensed facilities for which is no commercial disposal is available. The Department also is responsible for storing and disposing of sealed sources from the commercial sector under emergency conditions as requested by the Nuclear Regulatory Commission. The Department is in the process of defining the program for managing these wastes.

Low-level mixed waste is currently not disposed by the Department. Until the late 1980's, most of this waste was routinely disposed of by shallow land burial. However, the Resource Conservation and Recovery Act prohibits land disposal of low-level mixed waste that contains hazardous components subject to land disposal restrictions unless treatment standards are met or a variance is granted. By law, low-level mixed waste can be stored for 1 year only in facilities that meet specified requirements. The type of treatment depends on the chemical contaminants, radioactive contaminants, and the waste's physical form (e.g., liquid, solid, soil). Because of efforts to minimize the use of materials classified as hazardous under the Resource Conservation and Recovery Act, the bulk of the future inventory of low-level mixed waste will come from environmental restoration activities.

The Department is working with States to develop strategies to treat and dispose of these wastes. Issues include deciding on a location where wastes would be treated and defining the type of facility to be used, and location of disposal sites.

Hazardous waste is sent to commercial treatment and disposal facilities, for the most part. About 15,000 cubic meters are managed in approved commercial facilities annually. Little or no backlog of this waste awaits treatment and disposal, except for waste being accumulated for shipment to commercial facilities.

Sanitary waste is generated at all Department of Energy installations. It is disposed of onsite and offsite at Departmental, public, or private facilities.

2.3.3 Nuclear Material and Facility Stabilization

The end of the Cold War and subsequent decisions to stop the production of special nuclear materials made many Department of Energy facilities obsolete. Contaminated surplus facilities are being transferred from their current owners to the Environmental Management program. The mission of nuclear material and facility stabilization activities is to reduce the high-risk conditions associated with unstable excess nuclear and chemical materials left intact at former nuclear weapons production facilities and to reduce the maintenance costs associated with facilities awaiting decommissioning or final disposition. The transition process began in 1992. Of the approximately 3,500 contaminated facilities that exist, approximately 35 percent have already been transferred to Environmental Management; an additional 30 percent will be transferred by the year 2000; the remaining 35 percent will be transferred after 2000[1]. Following stabilization, the

(1) The list of 3,500 surplus facilities is a product of recently initiated efforts: the Surplus Facilities Inventory Assessment and the Draft Environmental Management Programmatic Environmental Impact Statement, and should not be considered conclusive. Excluded from this list are facilities that are expected to have a continued role in national security, such as the Naval Reactors Facility in Idaho, select Defense Program assets at the Pantex Plant in Texas, and national weapons laboratories in New Mexico and California.

Recent Nuclear Material and Facility Stabilization Activities

At the Savannah River Site, South Carolina:

- Initiated processing of approximately 80,000 gallons of plutonium nitrate solutions that were stranded in various process vessels in the F-Canyon separation facility when operations were shut down in March 1992.

At the Hanford Site, Washington:

- Remediated the plutonium bearing duct work in the support facility at the Plutonium Finishing Plant
- Completed stabilization of the Uranium Tri-Oxide Plant
- Reduced the contaminated area of the PUREX facility by 420,000 square feet, approximately 90 percent

At the Idaho Chemical Processing Plant, Idaho:

- Completed the uranium accountability at Buildings 601 and 602

At the Rocky Flats Environmental Technology Center, Colorado:

- Completed the solidification of 275 bottles of dilute plutonium solutions

majority of surplus facilities will be transferred to the Environmental Restoration program for decommissioning. Some will be dismantled while others may be released for continued industrial use.

Stabilizing and maintaining the large quantity of nuclear materials remaining in these "surplus" facilities is one of the most urgent tasks of the Environmental Management program. For example, reprocessing plants are no longer needed for the extraction of weapons-grade plutonium (although they may be needed to process some spent fuel for disposal), and the special nuclear materials inside of them are not intended to be used for nuclear weapons. The task of stabilizing these sensitive materials and facilities to prevent leaks, explosions, theft, or avoidable radiation or chemical exposures is part of the mission of Environmental Management.

Safeguarding surplus facilities is particularly difficult because many are more than 40 years old. They have reached or exceeded the lifetime for which they were designed and have begun to deteriorate; surveillance and maintenance of these facilities must be performed merely to ensure worker safety. Safe, stable conditions must be achieved, and the facilities and materials must be kept in a stable condition before any decontamination can be undertaken. This means, for example, that ventilation systems and air filters must work properly, and fire and radiation alarms must be tested.

Of the technical problems the Department faces in material and facility stabilization, plutonium is the most challenging. The sudden shutdown of plants that manufactured plutonium parts for nuclear weapons (the Rocky Flats Plant in Colorado and other plants at the Hanford and Savannah River Sites) stranded 26 metric tons of plutonium in a variety of forms—from plutonium dissolved in acid, and

rough pieces of metal, to nearly finished weapons parts. Unknown amounts have collected on the surfaces of ventilation ducts, air filters, and gloveboxes. Radioactivity from plutonium is slowly destroying the plastic bags and bottles that contain it. Flammable hydrogen gas is accumulating inside some sealed cans, drums, and bottles left in aisles and in gloveboxes. Bulging and ruptured containers already have been found in several places. A primary concern at the plants is worker safety, because plutonium is dangerous even in small quantities if inhaled as a dust. Plutonium metal can spontaneously explode and burn under certain conditions. Handling and storing plutonium requires special precautions to prevent such an occurrence of "nuclear criticality."

Many chemicals and chemical residues remained in containers or process lines when nuclear weapons production ended. The strategy for stabilizing chemicals emphasizes removing excess or unneeded chemicals, proper storage, and improved inventory tracking and control.

2.3.4 Technology Development

Developing new technologies to address the environmental challenges in the former nuclear weapons complex is an integral part of the Environmental Management program. This program also reflects our strategy of investing in technology development to develop long-term effective methods for addressing the unique environmental challenges facing the Department of Energy. The goals of technology development activities include reducing risks to people and the envi-

Technology Development Focus Areas

Treat and Dispose of Mixed Wastes. The Department is pursuing versatile treatment methods such as plasma, vitrification, molten metal, and non-thermal techniques. These activities are being coordinated closely with waste management activities to meet Federal Facility Compliance Act requirements.

Retrieve and Process Tank Wastes. The Department is initiating full-scale demonstrations on technology systems to safely retrieve and efficiently process high-level tank waste for permanent disposal. Tank structural analysis and waste content analysis methods are being developed.

Remediate Contaminated Soils and Ground Water. The Department has initiated full-scale demonstrations on technology systems to characterize, contain, and remediate contaminated plumes in soils and ground water. In-place treatment of dense non-aqueous phase liquids is one example.

Stabilize Landfills. Containment and in-place treatment methods for buried waste are being developed. Technology systems for retrieval, characterization, and treatment of landfill waste also are being pursued.

Stabilize, Decontaminate, and Decommission Facilities. The Department will conduct a full-scale demonstration for the development of facility stabilization and decommissioning technologies that emphasize the recycling of materials.

ronment, reducing cleanup costs, and finding new technologies to address environmental problems for which no solutions currently exist.

The Environmental Management program manages and coordinates an aggressive national program of applied research, development, demonstration, testing, and evaluation of new technologies for environmental restoration, waste management, and related activities. Technology Development's strategy is to identify and develop technologies that can clean up the nuclear weapons complex and manage waste more quickly, more safely, and at a lower cost. A good example is a technique known as "minimum-additive waste stabilization" that was demonstrated at the Fernald Site in Ohio to convert low-level radioactive waste into flattened glass pebbles. The pebbles are easy to handle and will remain stable after disposal. In many cases, developing new technologies presents the best hope for ensuring a real reduction in risk to the environment and improved worker and public safety.

Integrated demonstrations and other similar projects bring together technologies from national laboratories, other governmental agencies, and the private sector for demonstration, validation, and side-by-side comparison at a single test bed. Such efforts include nine projects for ground-water and soil remediation (e.g., volatile organic chemicals in non-arid soils, minimum additive waste stabilization) and seven projects for waste retrieval and processing (e.g., underground storage tanks, mixed waste). At least 24 technologies will be available for transfer to private industry and to Federal facilities as a result of these integrated projects.

2.3.5 Support Functions

To carry out its projects and activities, Environmental Management provides a variety of support functions. For simplicity, these are divided in this report into landlord functions and program direction and management.

Environmental Management "Landlord" Sites

Sites where Environmental Management is landlord include the following:

- Savannah River Site
- Hanford Site
- Oak Ridge K-25 Site
- Fernald Site
- Pinellas Plant
- Rocky Flats Site
- Idaho National Engineering Laboratory
- Grand Junction Projects Office
- Mound Plant
- Energy Technology Engineering Center

Landlord Functions

At 10 installations where the mission is predominantly environmental, the Environmental Management program is or will soon be landlord. At these installations, the Environmental Management program both oversees and directly pays for infrastructure and other site-wide support. West Valley and the Waste Isolation Pilot Plant landlord costs are included in the waste management program and not included in the separate landlord categorization.

As a landlord, the Environmental Management program is responsible for providing the support services and infrastructure required for continued operations. Many of these services are similar to those provided by local governments or as part of any industrial or commercial enterprise, such as building maintenance, maintenance of heating and air-conditioning equipment, groundskeeping, roadway upkeep, electrical distribution system and other utility maintenance, safeguards and security, radiation protection, transportation and hauling services, real-property management, and emergency preparedness. The Department's landlord activities also include a variety of unique support services because of the special nuclear materials and radiation/chemical hazards at installations. Landlord programs also often pay for other services, including medical services, information services, telecommunications, onsite transportation, laboratory support, general administration, and environmental monitoring.

Program Direction and Management

Program direction includes payments for Federal employee salaries, benefits, and training. Primary program management activities are (1) regulatory support, (2) operations integration, (3) program integration, and (4) program controls and analysis. Program management activities can support an entire site or a specific program such as waste management or environmental restoration.

The regulatory support activity includes regulatory oversight and programmatic guidance; implementation and monitoring compliance with pertinent environmental regulations and laws; and coordination of external surveillance, audits, and appraisals.

Operations integration involves developing, implementing, and conducting training programs; establishing and maintaining performance expectations and measurements; and preparing, reviewing, implementing, and maintaining procedures. Program integration requires development of near- and long-term plans for all remedial actions and waste streams, including coordination of private-sector initiatives, where appropriate.

Other important general activities of program management are quality assurance, information resource management, and program control and analysis. The latter includes preparing estimates, schedules, and budgets; budget- and schedule-variance analyses and corrective action; performance analyses; and funding management. Support to prepare the Baseline Report falls under this category.

3.0 The Base Case

This chapter presents the assumptions that define the Base Case cost estimate for the 1995 Baseline Report. The Base Case is premised on site-specific assumptions regarding future land use; treatment, storage, and disposal facility needs; and the technologies to be used at the sites. These assumptions were developed at individual sites and reflect specific regulatory requirements and site-specific planning efforts.[1] Because many assumptions are preliminary (i.e., they were made to estimate costs for activities that will happen decades from now), and will undoubtedly change in many cases, alternative cases are presented in Chapter 5 to demonstrate how the total program cost would vary as key assumptions are modified. Estimates of costs and projected schedules of activities for the Base Case are included in Chapter 4. A detailed discussion of the methodology used to develop the Base Case estimate is presented in Appendix C.

3.1 Estimating Costs in the Face of Large Uncertainties

Significant technical and institutional issues must be addressed to estimate cost and schedule for the complete life-cycle of the Environmental Management program. Technical issues result from the sheer magnitude of the program as well as the lack of data characterizing the levels of contamination at many sites. At the sites included in the program, the Department has identified a total of approximately 10,500 potential release sites from which contaminants could migrate into the environment. Although many of these units have been assessed for their contamination potential, only one-fourth of them have been fully characterized. Nonetheless, the Department believes it has characterized the largest and most significant of the 10,500 sites, and preliminary information is available for a substantial portion of the balance.

In other crucial areas, the problem is more clearly understood, but no solution currently is available, nor will be available for many years. An example is the need for a permanent isolation of high-level waste in a geologic repository—a repository will not be available for the Department's high-level waste until the year 2016. In other instances, no remedy for the problem is available or is even on the horizon. The contamination of soils deep underground from nuclear tests in Nevada is one such case. The costs to remediate these types of sites were excluded from the cost estimate, not because of a Departmental policy to ignore such problems, but rather, because no acceptable remediation strategy exists with today's technologies. Table 3.1 lists projects excluded from the analysis either because there is no technological solution, or if an activity were undertaken, it would cause more ecological harm than good.

In addition to the uncertainties that arise from the above-mentioned technical problems, the Environmental Management program is subject to uncertainties that

(1) For summary level site-specific assumptions, please refer to Volume II. For detailed assumptions, contact the site for access to the planning documents addressing facility and contamination release site assumptions.

Table 3.1. Examples of Remedial Action Cost Estimates Excluded from the Baseline Report

Installation	Project	Reason Excluded
Hanford Site	100 Area ground water 200 Area ground water Columbia River, Hanford Reach	No feasible remediation approach available
Oak Ridge Reservation (Y-12, K-25, Associated Universities)	Clinch River Watts Bar Reservoir Poplar Creek Embayment White Oak Creek	No feasible remediation approach available
Oak Ridge National Laboratory	Hydrofracture Site	No feasible remediation approach available
Savannah River Site	L Lake Savannah River Swamp Par Pond	Collateral ecological damage Collateral ecological damage Collateral ecological damage
Fernald Plant	Great Miami River	No feasible remediation approach available
Idaho National Engineering Laboratory	Snake River Plain Aquifer	No feasible remediation approach available
Rocky Flats Plant	West Spray Field Walnut Creek Woman Creek Great Western Reservoir Offsite surface soils	Collateral ecological damage
Nevada Test Site	Underground test areas	No feasible remediation approach available
Sandia National Laboratory	Chemical waste landfill ground water	No feasible remediation approach available

stem from its legal and institutional obligations. These include the legal requirements for an institutional framework that involves the U.S. Environmental Protection Agency and host States in making decisions about the majority of projects in the program. These participants make the final decisions about the choice of remedial action and the satisfactory completion of each action. In many cases, these decisions have not yet been made.

Furthermore, objectives have not been fully defined at some sites because the Department of Energy is not empowered to define them alone. For example, policy decisions related to preserving the interests of the Nation in regard to nuclear nonproliferation and defense readiness will define the future mission for the nuclear weapons complex. These policy decisions will affect the continued operations of some installations, including future land use options, and the final disposition of nuclear materials. These developments will affect the scope of the Environmental Management program in ways that are difficult to predict.

Finally, there is the length of the program—several decades. That in itself is sufficient to introduce a variety of uncertainties into any cost and schedule estimate. Some activities have been excluded from this analysis because of uncertainties described above. The disposition of excess weapons-grade plutonium was excluded, as was the disposition of materials not classified as waste and potential future projects that, if implemented, could generate waste (i.e., a new tritium reactor).

Despite the uncertainties, there is an important advantage in attempting to estimate costs before all this information is available or these decisions have been made. The cost consequences of different technical and policy options can be explicitly analyzed and debated to make wise decisions in an open manner. In addition to better departmental and congressional program management, this is exactly the point of the study.

3.2 Developing the Base Case

To develop the Base Case, available data were collected from all sites and assembled into an integrated and comprehensive whole. The data fell into four general categories: (1) estimates of the annual cost of each activity; (2) initial schedule estimates, including starting date and duration of the activity; (3) estimates of the annual waste volumes generated by each activity; and (4) assumptions regarding future land use and site mission, which tend to dictate the types of activities required. An "activity" is generally a specific set of actions taken to remediate a contaminated area, manage a facility, or manage a waste type at a site. The primary sources of these data were preliminary baselines developed by each site and other program planning documents. Approximately 60 percent of the Base Case life-cycle cost estimate was developed from these site-specific sources.

The remaining 40 percent of the cost estimate was developed through other sources. The missing information was generally future costs and schedules that were not completely estimated and key assumptions that were not addressed. Key assumptions regarding facility transfers to Environmental Management, availability of disposal facilities, and future land use were developed with input from stakeholders at meetings held to discuss methodology and assumptions. This was necessary because these assumptions are not defined in existing laws or policies, and because without these types of assumptions a total cost estimate is impossible to

develop. Gaps in cost estimates were filled using computer models developed to project costs associated with treating, storing, and disposing of projected waste volumes and completing remedial actions assumed to be necessary.

Key assumptions have an enormous influence on scope, schedule, and total cost of this program. The following sections describe key assumptions regarding funding availability and the major components of the Environmental Management program. Additional site-specific assumptions can be found in each site summary in Volume II of the Baseline Report.

3.3 Assumptions for the Base Case

3.3.1 Funding and Schedule Assumptions

The Environmental Management program operates under the same funding pressures as other Departments and Federal agencies. Although it is not possible to predict levels of Federal funding that may be available to support the program over the next several decades, assuming unlimited funding in any given time period is unrealistic. Moreover, there is a limited rate at which funds can be expended and still properly managed. Therefore, funding assumptions regarding the Base Case cost estimate were structured in such a way as to reflect realistic availability of future funding (i.e., under somewhat constrained budgets).

As specified by Congress, sites assumed a minimum funding level consistent with meeting the requirements of applicable laws, permits, regulations, orders, and agreements. In most cases, this involves meeting the milestones in the 72 existing compliance agreements in effect throughout the complex. About 65 percent of the near-term budget for the Environmental Management program is driven by compliance with these legal requirements. Of the remaining budget, approximately 25 percent of the costs go to vital nuclear material and safety responsibilities while the remainder goes to technology development and program management. Because the milestones in most compliance agreements do not extend beyond the year 2000, the funding available beyond that year was "capped" at the site's FY 2000 target level. In other words, annual site costs beyond the year 2000 were not permitted to exceed the funding cap unless cost increases were dictated by existing compliance agreements. This provided for an analysis that accommodated full funding for compliance commitments while ensuring the funding scenario for the program was realistic in light of other national priorities.

For purposes of the Base Case analysis, a site was considered "complete" when it had been remediated to the extent specified in land-use plans, all facilities had been properly stabilized and dispositioned, and waste had been safely disposed. Annual surveillance and monitoring costs were assumed to continue to be incurred after "completion" where restricted areas (e.g., waste disposal sites) were assumed to remain.

3.3.2 Environmental Restoration

The Base Case for environmental restoration encompasses activities at all sites in the Environmental Management program. These sites involve 10,500 potential release sites, which have been grouped into 614 subprojects, or operable units. For purposes of this report, the subprojects were further aggregated into 147 activities. The costs and schedules for each of these activities form the basis for tracking the costs of projects in Volume II. Examples of site-specific assumptions for environmental restoration activities are included in Table 3.2.

To establish the Base Case for environmental restoration, the Department depended primarily on ongoing baselining efforts. All sites in the complex have or are completing baseline estimates for all potential release sites and all surplus contaminated facilities that have been stabilized. These baselines embody an extensive set of site-specific assumptions about the nature and extent of contamination, ultimate land use, and remedial strategies. (The baseline documents are available in the local Department of Energy public reading rooms. See Appendix E for a list of reading rooms.)

One of the first tasks in developing the Base Case for environmental restoration was making assumptions about the extent and type of contamination at the potential release sites, because less than one-fourth of these release sites have been fully characterized. To the greatest extent possible, the Environmental Management program used assumptions made by program managers in the field because those managers have the best understanding of contamination problems. Field managers also are familiar with views of local stakeholders (regulators and affected public) about remedial approaches likely to be approved and about future land uses at the site.

Once a level of contamination has been established or assumed, remedial actions can be divided into two categories: those directed at containing contaminants to prevent them from migrating from the source, and those directed at eliminating the contamination. Remembering that radionuclides and other contaminants like heavy metals cannot be destroyed is important in understanding general assumptions about remediation. For these contaminants, only containment, either in place or after removal to some other location, is possible. Removal to another area allows contaminated soil, for example, from several areas to be consolidated and stabilized in one place. It also means creation of a disposal site that will, of necessity, require monitoring and restriction from public access for a long time.

Generally, the Base Case favors in-place containment over removal at large isolated facilities and at those sites likely to be used in the future for industrial purposes. Large sites in this category are Savannah River, Hanford, the Idaho National Engineering Laboratory, and the Nevada Test Site. At these sites, contaminated soil may be consolidated in one area or, if sufficiently concentrated, covered with a protective material (a clay or engineered cap) that prevents contaminants from being transported into ground water by rain or blown about by the wind.

Most buried wastes are assumed to be contained in place. In some cases, such as Pit 9 at the Radioactive Waste Management Complex in Idaho, they may be dug up to correct past disposal practices that may result in future risks to the public.

Table 3.2. Examples of Site-Specific Assumptions for Environmental Restoration Activities

Site Issue	Baseline Report Assumptions
Hanford	
• Reactors	• Reactor buildings decontaminated and demolished. • Reactor core blocks moved 15 miles to a disposal area.
• PUREX and other processing buildings	• Decontaminated, collapsed, and entombed in place.
• 200 Area	• 200 Area buildings would have their equipment removed, demolished, and buried onsite. All contaminated areas will be capped and monitored. Engineered barriers will be used to protect human health and the environment.
• Ground water	• Remediation of most ground water is not included in formulating the current baseline.
Savannah River Site	
• Canyons	• Buildings will be decontaminated; process equipment will be removed; structures are not assumed to be demolished.
• Reactors	• Reactors will remain in place once deactivated.
• Ground water	• Pump and treat operations, air stripping, and in-situ bioremediation. In areas where tritium is present (high-level waste tanks and reactor areas), assumes pump and treat to contain not remove contamination.
Idaho National Engineering Laboratory	
• Pit 9 and buried waste at Radioactive Waste Management Complex	• Excavate buried waste, segregate it, send transuranic waste to Waste Isolation Pilot Plant; return low-level waste to the Pit. The Pit will then be capped and monitored.
• Idaho Chemical Processing Plant	• All facilities deactivated, collapsed, and entombed in place.
Oak Ridge Reservation	
• Gaseous Diffusion Plants (K-25 Site, Portsmouth, Paducah)	• Deactivate and decontaminate the gaseous diffusion plants. Wastes will be disposed of at each site. Superstructure of the facilities will remain in place.
• Offsite Program	• No feasible technology available for the Clinch River, the Watts Bar Reservoir, and the Poplar Creek embayment. These sites are excluded from the analysis.
• Y-12	• Buildings assumed transferred to Environmental Management are decontaminated and prepared for reuse or demolished and capped. • Pump-and-treat contaminated ground water. • Contaminated soil is to be capped in place or relocated to another portion of the site and capped.
Rocky Flats Environmental Technology Site	
• 881 Hillside	• Contain and treat ground water.
• Solar Ponds	• Pond sludge solidified and shipped to the Nevada Test Site.
Fernald Environmental Management Project	
• Silos	• Residues and oxides will be vitrified, then sent to the Nevada Test Site. Concrete silo structures will be demolished, and debris will be buried onsite.
Nevada	
• Underground Test Area	• Excluded from analysis; no feasible remediation technology available.
• Soils	• Excavate areas with high levels of contamination; dispose in Areas 3 and 5.

The wastes would then be characterized and segregated by type. Heavily contaminated soil would be treated to destroy or stabilize contaminants, whereas soil with low levels of radioactive contamination would be returned to the ground and then capped.

Small buildings were assumed to be decontaminated and prepared for reuse or demolished. The large chemical processing buildings were generally assumed to be entombed by collapsing the contaminated structures and covering them with protective material or simply filling the voids and sealing them. For example, the reactors at the Hanford Site are assumed to be decontaminated and demolished except for the reactor blocks, which will be disposed of in one piece elsewhere at the site. The Savannah River reactors will be deactivated and left in place. Contamination at the Department's laboratories is assumed to be remediated; however, the missions of the laboratories are assumed to continue indefinitely.

At sites that are not owned by the Department, or are likely to be released for future residential use, generally a more active remedial approach is assumed. These sites are usually small and may be in heavily populated areas close to water sources. Examples are most of the Fernald site in Ohio; the General Atomics site in La Jolla, California; and Battelle Columbus Laboratories in Columbus, Ohio.

Ground-Water Contamination

Ground water has been contaminated at most major sites, the principal contaminants being volatile organic compounds, heavy metals, and radionuclides. Because current technologies are ineffective, Baseline Report estimates do not assume that all ground water will be remediated to drinking-water standards. Instead, the Baseline Report estimate reflects a spectrum of measures aimed mainly at preventing further contaminant migration and protecting offsite populations. The measures used in Baseline Report include the following:

- **Source elimination**. Most sites eliminate the source of the ground-water contamination by removing the contaminant or capping the contaminated area to prevent further leaching. Generally, the Baseline Report estimate includes the cost of source elimination at all sites.

- **Containment**. Some sites are planning to contain contaminant migration in ground water by using slurry walls, barriers, or innovative pumping actions. Where containment is the most cost-effective option, the Baseline Report estimate reflects it.

- **Natural attenuation**. The concentrations of some naturally occurring contaminants (e.g., uranium) in ground water will return to natural levels before the contaminants can reach any offsite users. And certain short-lived radionuclides (e.g., tritium) will decay to safe levels before they reach offsite receptors. Where natural attenuation is the assumed strategy, the Baseline Report estimate includes costs for monitoring but not for remediation.

- **Pumping and treating**. Costs for this remedial action are included in the Baseline Report estimate for a few sites, mainly those where remediation has already started (e.g., Kansas City Plant, Savannah River Site). Because this costly method can take many years, and its efficacy has not been established, it is not the dominant strategy reflected in the Baseline Report estimate.

Surface and ground-water contamination is a technical challenge for the program. Large river systems like the Columbia, Clinch, and Savannah rivers are not addressed because no effective remediation is available. For some other surface-water bodies, remediation is not planned because of potential ecological damage. Thus, in the Base Case, remediation of currently contaminated surface and ground waters accounts for less than 5 percent of the estimated total life-cycle cost of environmental restoration. The Department does, however, plan to monitor and contain contamination to the extent possible (see "Ground-Water Contamination" box). All primary sources of contaminants that can migrate to surface and ground water were assumed to be addressed by the program and are within the scope of the estimate. The Department hopes in the future to address these problems more effectively through technology development.

3.3.3 Waste Management

The Base Case estimates for waste management encompass (1) existing inventories from past generation, (2) new non-Environmental Management-generated waste, (3) secondary waste streams from environmental restoration activities, (4) waste from facility stabilization and maintenance activities, and (5) additional material generated by waste management activities.

Activities for waste management are defined as treatment, storage (and handling), and disposal of waste. These activities are detailed by waste type. Significant projects within these activities are discussed in Volume II.

For purposes of the Base Case analysis, configurations for treatment, storage, and disposal facilities were based on current agreements and negotiations as well as current operations. This includes treatment facilities in the Draft Site Treatment Plans, required by the Federal Facility Compliance Act, as well as current disposal operations of low-level waste at six facilities. See Table 3.3 for highlights of the Base Case assumptions for treatment, storage, and disposal.

Treatment

The Base Case includes four treatment projects, planned or in progress, for high-level waste stored in tanks at Hanford, the Savannah River site, the Idaho Chemical Processing Plant, and the West Valley in New York State. Two of these projects, the Defense Waste Processing Facility at Savannah River and the vitrification plant at the West Valley Demonstration Project, are nearing the start of operation. Planning continues for similar facilities at Hanford and Idaho. Secondary wastes (e.g., low-level and low-level mixed wastes) from these treatment facilities are assumed to be processed and prepared for disposal in approved facilities. The life-cycle costs cover all phases from planning through facility decommissioning.

Treatment facilities for low-level mixed waste are being planned through the consultation process under the Federal Facility Compliance Act. The Base Case includes treatment at 34 generator sites; this assumption is consistent with the Draft Site Treatment Plans developed in August 1994. The treatment facilities include new ones planned for large sites that will use a variety of technologies. Unless otherwise specified by an individual site, facilities are assumed to require 10 years for

Table 3.3. Base Case Waste Management Assumptions

Waste Type	Activity: Storage	Activity: Treatment	Activity: Disposal
High-Level Waste	• Continued storage in tanks at Hanford, Savannah River Site, and West Valley Demonstration Project • Continued storage of Calcine in bins at Idaho National Engineering Laboratory	• Vitrify at Hanford, Savannah River Site, West Valley Demonstration Project, and Idaho National Engineering Laboratory	• Geologic repository assumed available beginning in 2016
Spent Nuclear Fuel	• Continued storage at 10 sites, with majority at Hanford, Idaho National Engineering Laboratory, and Savannah River Site • Cost of building new storage facilities, both wet and dry included.	• No reprocessing	• Geologic repository assumed available in 2016
Transuranic Waste	• 10 installations, primarily at Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Savannah River Site	• Processed to meet disposal criteria	• The Waste Isolation Pilot Plant beginning in 1998
Low-Level Mixed Waste	• Storage at more than 30 generator sites	• Land disposal restrictions met • Treatment performed at 34 sites	• Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, Oak Ridge, Savannah River Site • Western sites will use shallow land disposal techniques, eastern sites will use an engineered disposal technique
Low-Level Waste	• Storage at generator sites while waiting for disposal at six Department of Energy sites	• Minimal treatment to meet transport and disposal criteria	• Disposal onsite at Hanford, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Nevada Test Site, Oak Ridge, Savannah River Site • Western sites will use shallow land disposal techniques, eastern sites will use an engineered disposal technique

research, development, design, permitting, construction, and start-up activities. Facilities are assumed to have 30 years of operation capability. Smaller sites are considering mobile treatment units or using new or existing facilities. Life-cycle costs cover all phases from planning through facility decommissioning. The Base Case reflects site-specific planning assumptions, which may include the use of commercial facilities.

Treatment for low-level and transuranic waste consists of characterization, packaging, and, if necessary, processing to meet criteria for disposal. In the Base Case, these functions are performed at the generating sites.

All sites manage hazardous and sanitary wastes within their waste management programs. The estimate includes life-cycle costs for collection, treatment, and disposal of sanitary and hazardous wastes generated by Environmental Management activities. For this estimate, current costs for treatment and disposal of these materials were assumed to remain constant and that adequate capacity and availability would continue.

Storage and Handling

High-level waste is stored either in tanks or bins at Hanford, Savannah River, the Idaho Chemical Processing Plant, and West Valley. The Base Case cost estimate includes complete life-cycle costs for the tank farms, storage facilities, and transfer facilities. Costs include facility upgrades and decommissioning once the mission is complete. The estimate also includes costs for storing canisters of vitrified high-level waste pending disposal in a repository.

Spent nuclear fuel is currently stored at 13 sites within the complex, with approximately 99 percent stored at the Hanford Site, the Idaho National Engineering Laboratory, the Savannah River Site, and the Oak Ridge Reservation. The Base Case cost estimate includes life-cycle costs of storing spent nuclear fuel prior to disposal at a national geologic repository, which is assumed to be available by 2016. The Base Case does not include costs for the remaining 1 percent of spent fuel stored at various locations throughout the complex. It is assumed that no spent nuclear fuel will be reprocessed in the future.

Transuranic wastes are stored at 10 installations, primarily Idaho National Engineering Laboratory, Hanford, Savannah River, and Los Alamos National Laboratory. The Base Case includes existing and additional facilities to store, characterize, and treat waste to current waste acceptance criteria for the Waste Isolation Pilot Plant.

Low-level mixed wastes are stored in approved facilities pending the availability of treatment facilities. Life-cycle costs cover planning through decommissioning, for both existing and additional facilities.

Disposal

High-level waste and spent nuclear fuel will eventually be disposed of in a deep geologic repository developed and operated by the Department's Office of Civilian Radioactive Waste Management. For purposes of this analysis, it was assumed that Department wastes would be accepted by the repository beginning in 2016. In the Base Case, costs are included for disposal fees.

Transuranic waste is stored in a retrievable manner pending the opening of a geologic repository. For the purpose of this Baseline Report, it is assumed that the Waste Isolation Pilot Plant will start accepting waste in 1998.

Low-level waste continues to be disposed of at the existing six disposal sites: Hanford, Savannah River, the Oak Ridge Reservation, Los Alamos National Laboratory, Idaho National Engineering Laboratory, and the Nevada Test Site. Engineered disposal vaults are assumed at Savannah River and Oak Ridge. Shallow land disposal was assumed to continue at the remaining sites. Life-cycle costs are included for continued operations through closure, which is assumed to occur at the completion of all Environmental Management activities at the installation and post-closure monitoring.

Low-level mixed waste, after treatment to meet regulatory standards, is assumed to be disposed of in approved disposal facilities. The Base Case assumes that disposal facilities for low-level mixed waste will be provided at the six sites (see above) where low-level waste is disposed. Life-cycle costs are included from early planning through post-closure monitoring (until 2070).

Examples of Facility Categories

Fourteen **large production reactors** designed for the production of nuclear materials (e.g., plutonium and tritium). These large, complex facilities have extensive support structures for nuclear fuel storage, handling, and processing. Such reactors are located at the Savannah River Site in South Carolina and the Hanford Site in Washington State.

Eight **chemical processing plants** designed to process spent nuclear fuel for the recovery of nuclear materials. These are very complex facilities with vast arrays of piping, duct-work, and support structures required for handling and storing spent fuel, high-level radioactive waste, and mixed waste. These facilities are located at Hanford, the Idaho National Engineering Laboratory, and Savannah River sites.

Other radiologically contaminated buildings include the largest number of contaminated structures in the Department of Energy inventory of surplus buildings. They range from small storage buildings of several hundred square feet to large milling, manufacturing, and assembly facilities. Buildings contaminated with both radiological and chemical constituents are included in this category and are present at almost every Department of Energy site across the country.

Buildings contaminated with hazardous materials occur across the Department of Energy complex and include those structures contaminated with hazardous chemicals, primarily organic solvents, and metals. Although widely dispersed, these facilities are usually associated with research and development operations conducted at national laboratories.

Research reactors are designed to study new technology for power generation, nuclear materials production, or propulsion (e.g., nuclear-naval vessels). Although not physically as large as production reactors, these facilities are just as complex and contain similar contaminants. Some of the major Department of Energy research reactor locations include Idaho National Engineering Laboratory, Savannah River Site, and Oak Ridge Reservation.

3.3.4 Nuclear Material and Facility Stabilization

Some 3,500 contaminated facilities are in the process of being turned over to Environmental Management for stabilization and maintenance. These facilities were divided into 22 categories based on their physical characteristics. Examples of facility categories include large production reactors, chemical processing buildings, and research reactors (see following box). Because these surplus facilities will not undergo transition immediately or simultaneously, it was necessary to make assumptions for the Base Case regarding schedules for facility transfers. Additionally, schedule assumptions had to be made regarding how long a facility would undergo surveillance and maintenance before and after stabilization, as well as the duration of stabilization activities.

For the Base Case, the following hypothetical scheduling scenario was assumed for each facility: 10 years of surveillance and maintenance after the transfer of a facility to Environmental Management, followed by 5 years of stabilization activities and 2 years of post-deactivation surveillance and maintenance before final disposition. Facilities already transferred to Environmental Management were scheduled according to the hypothetical "10-5-2" scenario, depending on how far along they are in the process. The remaining majority of facilities were assigned arbitrary transfer dates, which were typically selected to fit within funding constraints assumed for the Base Case. No attempt was made to schedule these facilities according to risk or other priorities. Therefore, the 10-5-2 schedule scenario, with its uniform assumptions for all facilities, is hypothetical and by no means represents the way facilities will actually be handled.

In the Base Case, surveillance and maintenance encompasses all actions required to ensure adequate safety and security pending the ultimate disposition of the surplus facility. Surveillance and maintenance is assumed to continue during the stabilization step as well. Stabilization entails eliminating immediate safety and environmental hazards as well as removing most contaminants from the facility. The costs for managing waste generated by these activities are included in waste management costs.

Nuclear material and facility stabilization has less than 3 years of experience to draw on, and thus its data base is very limited. Most cost data were extrapolated based on a limited number of projects recently initiated at the Hanford, Idaho, Savannah River, Oak Ridge, and Rocky Flats sites. Because the nuclear material and facility stabilization activities are typically not driven by regulatory requirements, they were often scheduled to take place later rather that sooner.

Therefore, the Base Case does not demonstrate the savings that could be realized in reducing the cost of surveillance and maintenance by accelerating the start of stabilization for nuclear materials and surplus facilities. This case is explored in Chapter 5.

3.3.5 Technology Development

The primary assumption regarding technology development is that only existing technologies will be available over the life of the program. As such, the description of technologies to be used in the program is inherent in the descriptions of waste

Table 3.5. Sites with Environmental Management Activities in the 1995 Baseline Report

State	
Alaska	Amchitka Island Test Site (reported under Nevada Offsite* - Alaska)
Arizona	Monument Valley (reported under completed UMTRA S&M** - Arizona) Tuba City (reported under completed UMTRA S&M - Arizona)
California	Energy Technology Engineering Center General Atomics General Electric Vallecitos Nuclear Center Geothermal Test Facility Laboratory for Energy-Related Health Research Lawrence Berkeley Laboratory Lawerence Livermore National Laboratory Oxnard Rockwell International (reported under Energy Technology Engineering Center) Salton Sea Test Base (reported under Sandia National Laboratories - Albuquerque) Sandia National Laboratories, Livermore Stanford Linear Accelerator
Colorado	Durango (reported under completed UMTRA S&M - Colorado) Grand Junction Projects Office Site Gunnison Maybell Naturita Project Rio Blanco (reported under Nevada Offsite - Colorado) Project Rulison (reported under Nevada Offsite - Colorado) Old/New Rifle Old North Continent/Union Carbide, Slick Rock Rocky Flats Environmental Technology Site
Connecticut	Combustion Engineering Site (reported under FUSRAP*** - Connecticut)
Florida	Peak Oil Petroleum Refining Plant (reported under Pinellas Plant) Pinellas Plant 4.5 Acre Site (reported under Pinellas Plant)
Hawaii	Kauai Test Facility (reported under Sandia National Laboratories - Albuquerque)
Idaho	Argonne National Laboratory - West Idaho National Engineering Laboratory Lowman (reported under completed UMTRA S&M - Idaho)
Illinois	Argonne National Laboratory - East Fermi National Accelerator Laboratory Madison (reported under FUSRAP - Illinois) Site A/Plot M
Iowa	Ames Laboratory
Kentucky	Maxey Flats Paducah Gaseous Diffusion Plant
Maryland/ Washington D.C.	W.R. Grace & Co. (reported under FUSRAP - Maryland) Environmental Management Program Headquarters****
Massachusetts	Chapman (reported under FUSRAP - Massachusetts) Shpack Landfill (reported under FUSRAP - Massachusetts) Ventron (reported under FUSRAP - Massachusetts)
Michigan	General Motors (reported under FUSRAP - Michigan)
Mississippi	Salmon Peaceful Nuclear Explosion Site (reported under Nevada Offsite - Mississippi)
Missouri	Kansas City Plant Latty Avenue Properties (reported under FUSRAP - Missouri) St. Louis Airport (reported under FUSRAP - Missouri) St. Louis Airport Vicinity Properties (reported under FUSRAP - Missouri) St. Louis Downtown Site (reported under FUSRAP - Missouri) Weldon Spring Site Remedial Action Project
Nebraska	Hallam Nuclear Power Facility

*Nevada Offsite are locations where nuclear detonations occurred and environmental management activities are managed by the Nevada Operations Office.
** UMTRA S&M is the acronym for Uranium Mill Tailings Remedial Action projects with long-term Surveillance and Maintenance activities.
***FUSRAP is the acronym for the Formerly Utilized Sites Remedial Action Program.
****Approximately 71 percent of these costs are distributed across Environmental Management sites.

Table 3.5. Sites with Environmental Management Activities in the 1995 Baseline Report (contd.)

State	
Nevada	Central Nevada Test Area (reported under Nevada Offsite - Nevada) Nevada Test Site Project Shoal (reported under Nevada Offsite - Nevada) Tonopah Test Range (reported under Nevada Offsite - Nevada)
New Jersey	Du Pont / Chambers Dye Works (reported under FUSRAP - New Jersey) Maywood Chemical (reported under FUSRAP - New Jersey) Middlesex Sampling Plant (reported under FUSRAP - New Jersey) New Brunswick Laboratory (reported under FUSRAP - New Jersey) Princeton Plasma Physics Laboratory Wayne Interim Storage Site (reported under FUSRAP - New Jersey)
New Mexico	Albuquerque Operations Office Ambrosia Lake Holloman Air Force Base (reported under Sandia National Laboratories - Albuquerque) Inhalation Toxicology Research Institute Los Alamos National Laboratory Project Gasbuggy (reported under Nevada Offsite - New Mexico) Project Gnome (reported under Nevada Offsite - New Mexico) Sandia National Laboratories, Albuquerque Shiprock (reported under completed UMTRA S&M - New Mexico) South Valley Site Waste Isolation Pilot Plant
New York	Ashland Oil Co. (reported under FUSRAP - New York) Bliss & Laughlin (reported under FUSRAP - New York) Brookhaven National Laboratory Colonie Intermin Storage (reported under FUSRAP - New York) Linde Air Products (reported under FUSRAP - New York) Seaway Industrial Park (reported under FUSRAP - New York) Separations Process Research Unit West Valley Demonstration Project
North Dakota	Belfield Bowman
Ohio	Alba Craft (reported under FUSRAP - Ohio) Associated Aircraft and Tool Manufacturing (reported under FUSRAP - Ohio) B&T Metals (reported under FUSRAP - Ohio) Baker Bros. (reported under FUSRAP - Ohio) Battelle Columbus Laboratories Fernald Environmental Management Project HHM Safe Site (reported under FUSRAP - Ohio) Luckey Site (reported under FUSRAP - Ohio) Mound Plant Painesville Site (reported under FUSRAP - Ohio) Piqua Nuclear Power Facilty Portsmouth Gaseous Diffusion Plant Reactive Metals, Inc.
Oregon	Lakeview (reported under completed UMTRA Site S&M - Oregon)
Pennsylvania	Canonsburg (reported under completed UMTRA Site S&M - Pennsylvania)
South Carolina	Savannah River Site
Tennessee	K-25 Site Oak Ridge Reservation Oak Ridge Associated Universities Oak Ridge National Laboratory Y-12 Plant
Texas	Falls City (reported under completed UMTRA Site S&M - Texas) Pantex Plant
Utah	Green River (reported under completed UMTRA Site S&M - Utah) Mexican Hat (reported under completed UMTRA Site S&M - Utah) Monticello Millsite and Vicinity Properties Salt Lake City (reported under completed UMTRA Site S&M - Utah)
Washington	Hanford Site
Wyoming	Riverton (reported under completed UMTRA Site S&M - Wyoming) Spook (reported under completed UMTRA Site S&M - Wyoming)

- **Included in Other Site Estimates**. Estimates for 6 of the aggregated sites are included in estimates for other sites. For these sites, Rockwell International (California) is included in the estimate for the Energy Technology Engineering Center (California); Salton Sea Test Base (California), Kauai Test Facility (Hawaii), and Holloman Air Force Base (New Mexico) are included in the offsite estimates for Sandia National Laboratories—Albuquerque (New Mexico); and Peak Oil Petroleum Refining Plant (Florida) and 4.5 Acre Site (Florida) are included in the estimates for Pinellas Plant (Florida).

A total of 25 sites are not included in the analysis for the Baseline Report. These sites are completed or are excluded because of inadequate information. These 25 sites include:

- **Completed Sites**. Of the 25 excluded sites, remediation is complete at 21 of the sites, and no long-term monitoring or operations costs are included in the report. These sites are Cape Thompson (Alaska), University of California Gilman Hall (California), Seymour Specialty Wire Co. (Connecticut), Granite City (Illinois), Illinois National Guard Armory (Illinois), University of Chicago (Illinois), Kellex/Pierpont (New Jersey), Middlesex Municipal Landfill (New Jersey), Acid/Pueblo Canyon (New Mexico), Bayo Canyon (New Mexico), Chupadera Mesa (New Mexico), Pagano Salvage Yard (New Mexico), Baker and Williams Warehouse (New York), Niagara Falls Storage Site (New York), Niagara Falls Storage Site Vicinity Property (New York), Albany Research Center (Oregon), Aliquippa Forge (Pennsylvania), C.H. Schnoor (Pennsylvania), Shippingport Atomic Power Station (Pennsylvania), Edgemont Vicinity Properties (South Dakota), and Elza Gate Site (Tennessee).

- **Excluded Sites**. Four of the sites have been excluded from the analysis because of insufficient information on the future cost and schedule of environmental management activities at these sites. These sites are Component Development and Integration Site (Montana), Center for Energy and Environmental Research (Puerto Rico), Bikini Island (South Pacific Ocean), and Enewetak Atoll (South Pacific Ocean).

Finally, the treatment, storage, and disposal of radioactively contaminated waste from more than 10 sites not included in the list of sites for which Environmental Management has environmental restoration responsibility are included in the Baseline Report. Although these sites are not the responsibility of the Environmental Management program, waste from these sites is included in the estimate. These sites are Bettis Atomic Power Laboratory, Knolls Kesselring, Knolls Schenectady, Knolls Windsor, Mare Island Naval Station, Norfolk Naval Station, Naval Reactor Site, Pearl Harbor Naval Station, Portsmouth Naval Station, and Puget Sound Naval Station.

4.0 Results

This chapter presents the cost and schedule estimates mandated by Congress in the Fiscal Year 1994 National Defense Authorization Act. As required by the Act, the scope of the estimate includes all activities necessary to carry out the environmental restoration and waste management activities associated with the Department's defense nuclear facilities. Although not specifically requested by Congress, the costs incurred by the Environmental Management program to address nondefense waste and restoration activities are also presented for completeness. The estimates, therefore, reflect the total "life-cycle" cost of the Environmental Management program.

The chapter provides estimates for the "Base Case" scenario, which represents current site-specific assumptions about the most likely set of activities and projects envisioned to form the program (see Section 3.3). Because many key policy decisions affecting the cost of the Base Case remain uncertain, the program's life-cycle costs also are examined (in Chapter 5) under different sets of assumptions for comparison to the Base Case estimate.

The Baseline Report Is Not a Budget Document

The purpose of the Baseline Report is to provide a total long-term (life-cycle) cost estimate for the Environmental Management program. The Baseline Report is not intended to be a budget document, and none of the estimates given in the document should be interpreted as Federal budget requests.

Furthermore, the schedule of activities presented in the Baseline Report should not be interpreted as establishing specific long-term priorities or construed as a definitive basis for planning specific projects. Too many decisions that will affect the strategic long-term goals for the program are yet to be made. The issues underlying these decisions, such as future land use, funding availability, and acceptable levels of residual contamination, will be resolved over several years in conjunction with broad public discussion. Fostering and informing this discussion is a key purpose of this analysis.

4.1 The Total Life-Cycle Cost of the Environmental Management Program

Under the Base Case assumptions, the life-cycle cost estimate to complete the Environmental Management program ranges from $200 to $350 billion with a midrange estimate of $230 billion. All estimates are in constant 1995 dollars (see the box on p. 4.2 for a discussion of constant versus current dollars). These three estimates reflect different assumptions regarding productivity improvement over the life of the program. The life-cycle cost profiles are graphically depicted in Figure 4.1.

The high end of the cost range—$350 billion—represents the sum of life-cycle costs of all site-specific activities and projects described in Volume II of the Baseline Report. This figure, however, does not account for the substantial cost savings expected from progress in changing the way the Office of Environmental

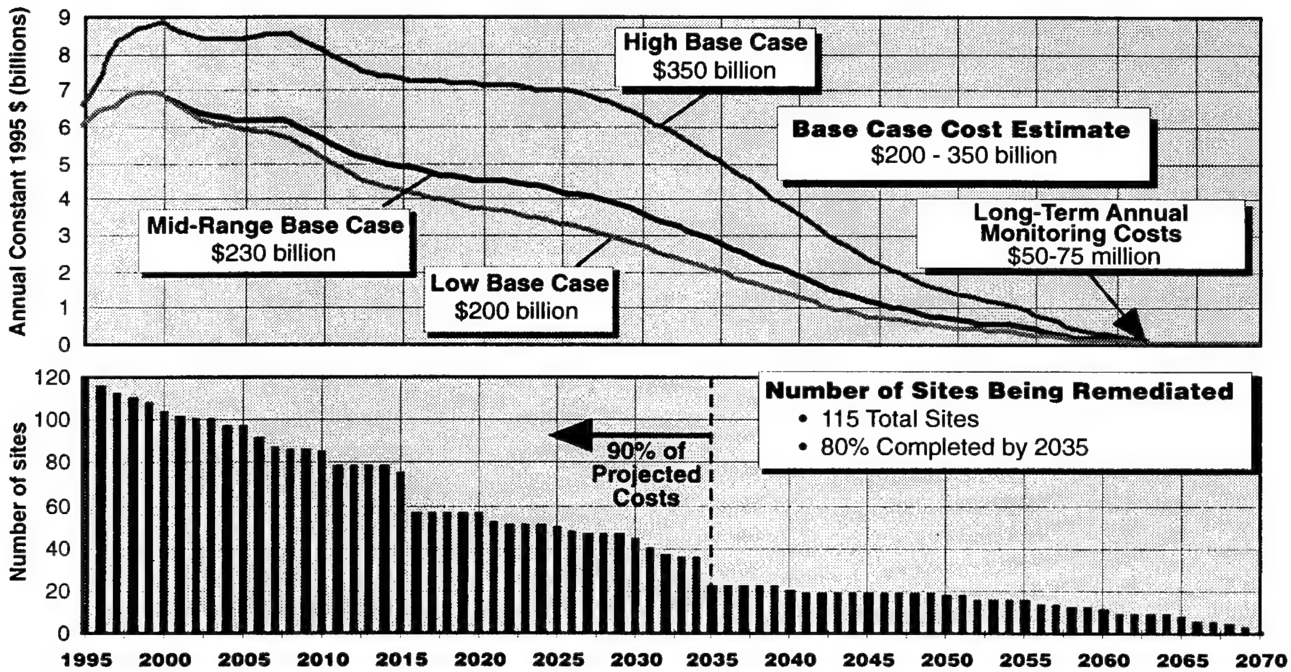


Figure 4.1. Base Case Cost and Schedule Estimate

Management conducts its business or savings it may achieve by aggressively seeking opportunities to increase productivity or applying advanced technologies over the life of the program.

Because of these efforts, Environmental Management believes the program will demonstrate substantial improvements in productivity over the next 5 years and continue these improvements over the life of the program. Before the year 2000, Environmental Management hopes to achieve an approximately 20-percent increase in productivity and efficiency. These improvements would result in a savings of approximately $8 billion over the next 5 years. Improvements would be realized through activities currently being implemented such as reductions in indirect and overhead costs, contract reform, privatization, and workforce reduction. Productivity gains realized by the year 2000 are assumed to affect costs for the life of the program. For example, more efficient procurement practices, adoption of more efficient technologies, and improved organizational learning initiated before the year 2000 will continue to yield future savings. Appendix D provides more details on initiatives that will be implemented to achieve productivity savings.

Constant vs. Current Dollars

Constant dollars represent a dollar value adjusted for changes in prices. Dollars in the future are adjusted by removing inflation. Unless otherwise noted, all 1995 Baseline Report cost projections are in constant 1995 dollars.

Current dollars represent the dollar value of goods or services in terms of prices current at the time the goods or services were sold (in other words, inflation[1] is included in the numbers).

(1) The inflation factors are 3 percent in 1996, 3.1 percent in 1997, and 3.2 percent in 1998 and beyond. These factors are based on Office of Management and Budget, *FY 1995 Budget of the United States Government.*

Beyond the year 2000 as the program matures, the Department expects to continue its productivity improvements but at a reduced rate. Historically, a sustained productivity improvement rate of 1 percent annually is typical of public sector organizations.[1] Such rates are realized as a program naturally matures and may also result from applying advanced technologies. (Chapter 5 provides examples of potential savings that could be achieved by applying advanced technology).

Assuming the Environmental Management program will realize a 20-percent increase in productivity and efficiency over the next 5 years, and sustain a 1-percent annual improvement in productivity over the remaining life of the program, the total life-cycle cost estimate is $230 billion. This mid-range estimate, adjusted for expected savings, is judged to be more representative of the total cost of the Environmental Management program than the high estimate. The discussion of Baseline Report results focuses on this estimate. Over the lifetime of the program, productivity savings amount to $120 billion compared to the initial estimate. Table 4.1 shows the annual breakdown of the Base Case cost estimate.

Under a more aggressive efficiency and productivity improvement program, or with greater breakthroughs in technology development, life-cycle costs could be further reduced. For example, if productivity were to grow beyond 2000 at a rate similar to that of private industry (close to 2 percent per year), the life-cycle cost estimate would be approximately $200 billion. This more aggressive improvement in productivity yields an additional savings of $30 billion over that projected for the mid-range case.

What is the Life-Cycle?

Congress requested an estimate of the total cost of the Environmental Management program, which is referred to throughout the Baseline Report as the life-cycle cost. Base Case life-cycle costs are incurred over approximately 75 years. This is because scheduling under the Base Case assumes most activities are completed by approximately 2070. The availability of more or less funding than assumed for this analysis would, however, affect the length of the program.

The Base Case cost estimate does not include costs expended before 1995 (approximately $23 billion since the Environmental Management program was established in October 1989). It also does not include costs projected beyond 2070 associated with monitoring and maintaining disposal sites and other restricted-access areas, estimated to be $50 to $75 million per year, and costs of managing wastes from ongoing activities (e.g., basic research and nuclear weapons maintenance), estimated at approximately $300 million annually.

(1) Bureau of Labor Statistics. *Productivity Measures in Selected Industries and Government Services.* March 1994.

Table 4.1. Life-Cycle Cost Estimates for the Low, Mid-Range, and High Base Case

Year	Mid-Range Estimate (constant 1995 $ billions)	Mid-Range Estimate (1) (current $ billions)	Low Estimate (constant 1995 $ billions)	High Estimate (constant 1995 $ billions)
1995-2000	39	44	39	48
2001-2005	31	41	30	42
2006-2010	30	47	28	42
2011-2015	25	46	22	37
2016-2020	23	49	20	36
2021-2025	22	54	17	35
2026-2030	19	57	15	33
2031-2035	15	52	11	28
2036-2040	11	44	8	21
2041-2045	7	31	5	13
2046-2050	4	21	3	8
2051-2055	3	16	1	5
2056-2060	1	5	<1	2
2061-2065	<1	<1	<1	<1
2066-2070	<1	<1	<1	<1
Total Cost:	230	507	200	350

(1) The inflation factors are 3 percent in 1996, 3.1 percent in 1997, and 3.2 percent in 1998 and beyond. These factors are based on Office of Management and Budget, *FY 1995 Budget of the United States Government.*

Examining the cost estimates reveals a number of key issues. First, costs increase sharply from the present until the year 2000. These costs reflect aggressive activity in all program areas. For example, activities include construction and operation of waste treatment facilities at several major sites, shifting from characterization to active remediation at restoration sites across the complex and deactivation of major facilities. Costs for these activities hold fairly constant for about a decade and slowly decline to the year 2025 at which time they begin to fall off more sharply. Given the Base Case scheduling assumptions, this falling off reflects completion of the majority of work on the large components of the program, including tank remediation activities for high-level waste, decommissioning of most large structures across the complex, and construction activities for environmental restoration. Finally, almost 90 percent of the life-cycle estimate is scheduled before the year 2035. Remaining costs are primarily from environmental restoration activity at the large sites.

In the Base Case estimates, costs of treating and disposing of waste generated by facilities in other Department of Energy programs (e.g., Los Alamos National Laboratory, Princeton Plasma Physics Laboratory, and Brookhaven National Laboratory) were cut off at the year 2030. If these programs were to continue, costs to manage wastes from such ongoing activities would be incurred, perhaps by Environmental Management, for as long as the facilities operated. The annual rate in the year 2030 is approximately $300 million. If one assumed these costs were borne by Environmental Management over the life of the program (i.e., until 2070), they would add approximately $12 billion to the Base Case mid-range cost estimate.

Finally, the annual costs at the program's completion do not reach zero because of "post-operational" expenditures (e.g., long-term surveillance and maintenance). These costs were not analyzed on a site-specific basis and are expected to vary widely from site to site. For example, costs to monitor the Waste Isolation Pilot

Plant repository in New Mexico would be significantly greater than those to monitor a small site not used for disposal like the Pinellas Plant in Florida. Post-operational activities focus on sampling, analyzing monitoring well data, maintaining protective covering or barriers, and providing for active institutional controls at near-surface and deep geologic disposal sites where long-lived radioactive wastes were left in place. Preliminary estimates indicate these long-term costs would range from $50 to 75 million annually for several decades.

4.1.1 The Administration's Budget and the 1995 Baseline Report

Figure 4.2 compares the Baseline Report cost estimate and the Administration's FY 1996 budget and outyear projections. The Administration has established budget targets for the next 5 years that reflect the allocation of resources among competing national priorities, including lower taxes and deficit reduction. These targets move the Environmental Management program from $6.6 billion in FY 1996 to $5.5 billion in FY 2000 in current dollars. This equates to a target of $4.7 billion in constant 1995 dollars in FY 2000. For purposes of this comparison, this target is assumed to remain unchanged over the life of the Environmental Management program.

A shortfall remains between the Base Case cost estimate (i.e., the estimated cost of meeting compliance agreements) and the Environmental Management program's FY 1996 funding request and outyear targets. For the high Base Case estimate, this shortfall would be approximately $100 billion over the next 40 years without pro-

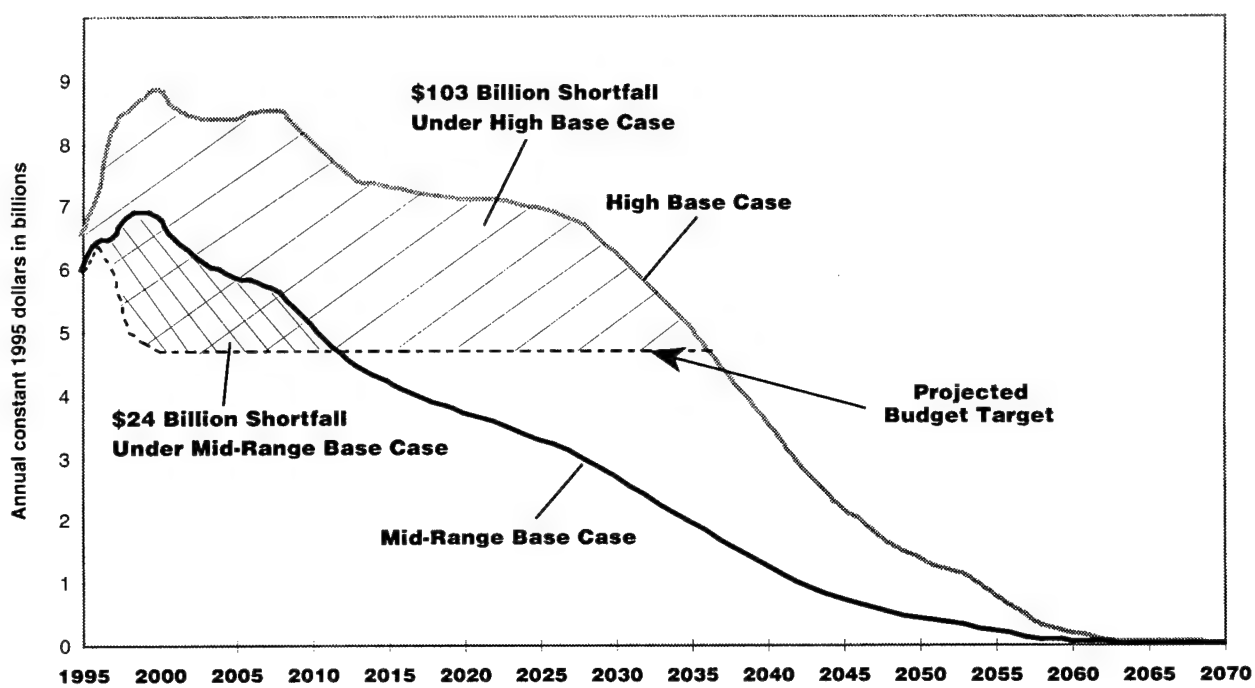


Figure 4.2. Comparison Between the Base Case Cost Estimates and the Administration's Budget Projection

ductivity improvements. With the mid-range Base Case estimate, this shortfall is $24 billion through the year 2015, at which point the hypothetical target would match projected needs. Savings of approximately $8 billion from the assumed 20 percent productivity improvement over the next 5 years begins to bridge this gap. However, even with these savings, a shortfall remains of approximately $7 billion through FY 2000.

To address this immense challenge, the Department must continue to be smarter about the way it operates by streamlining its contractor workforce, reducing indirect and overhead labor costs, and reforming its contracting process. Specific priorities include the following:

- hiring 1600 experienced project managers, cost estimators, safety and health professionals, and environmental engineers to provide greater accountability and oversight at Department of Energy sites;
- renegotiating $30 billion worth of contracts to include greater incentives for outstanding performance and to ensure that contractors take on a larger share of risks associated with doing business;
- reducing the number of contractor employees by about 34 percent from 1994-1996, in accordance with Section 3161 of the Defense Authorization Act of 1993; and
- providing greater flexibility at the site level to direct resources to activities that most reduce urgent risks and threats to workers and public health and safety.

In addition, the Department is supporting legislative changes to form a more efficient and cost-effective framework for assessing and reducing public health and safety risks. A key factor in legislative reform is reauthorizing Superfund, particularly to incorporate the land-use provisions in the Administration's Superfund proposal.

Most importantly, the Department has begun and will continue to work cooperatively with States and other stakeholders to develop more achievable, effective risk-based compliance agreements.

4.1.2 Uncertainty of the Estimate

In addition to the uncertainty surrounding outyear productivity, a range of uncertainty also is inherent in projecting the costs of any project. Projects that are well defined and use proven technology have a narrow range of uncertainty, often less than 5 percent above and below the most likely estimate. However, certain classes of projects, especially extremely complex projects, based mainly on new technology, and subject to substantial changes in scope, have a very broad range of estimate uncertainty. Other factors contributing to estimate uncertainty include errors in estimating unit costs and labor productivity, schedule delays, unexpected fees, and even simple errors in arithmetic. Estimate uncertainty also relates to the phase of the project. As a project nears completion, the range of uncertainty narrows. Changes in basic project assumptions and scope are the greatest contributor to errors in cost estimation. Several of these larger programmatic issues (e.g., changes in future land-use assumptions and their associated influence on the cost estimate) are addressed in Chapter 5.

To more accurately portray the 1995 Baseline Report cost estimate, an uncertainty range can be added to any of the Base Case cost estimates (see Figure 4.3). Using definitions provided by the American Association of Cost Engineers[1], the near-term estimates (next 5 years) are assumed to be definitive estimates with an error range of 10 percent above and 5 percent below the Base Case estimate. All estimates beyond the year 2000 are assumed to be conceptual estimates with an uncertainty range of 50 percent above and 30 percent below the Base Case estimates. Applying these uncertainty assumptions to the mid-range Base Case estimate yields a total life-cycle cost range from $170 billion to $330 billion for the low-uncertainty and high-uncertainty cases, respectively.

4.2 Base Case Estimate for Major Elements of the Environmental Management Program

The mid-range Base Case life-cycle estimate for the major elements of the Environmental Management program is shown in Figures 4.4 and 4.5. The program is divided into five major cost elements: waste management, environmental restoration, nuclear material and facility stabilization, technology development, and national program management. Table 4.2 presents examples of the magnitude of total cost for major projects across the complex.

Waste management activities account for $112 billion of the projected estimate and represent the largest share (49 percent) of the total life-cycle program costs. After an initial increase in waste management costs to the year 2000, costs in Figure 4.5 are seen to decline steadily until the year 2060. Costs associated with managing high-level radioactive waste are the largest component of the program and

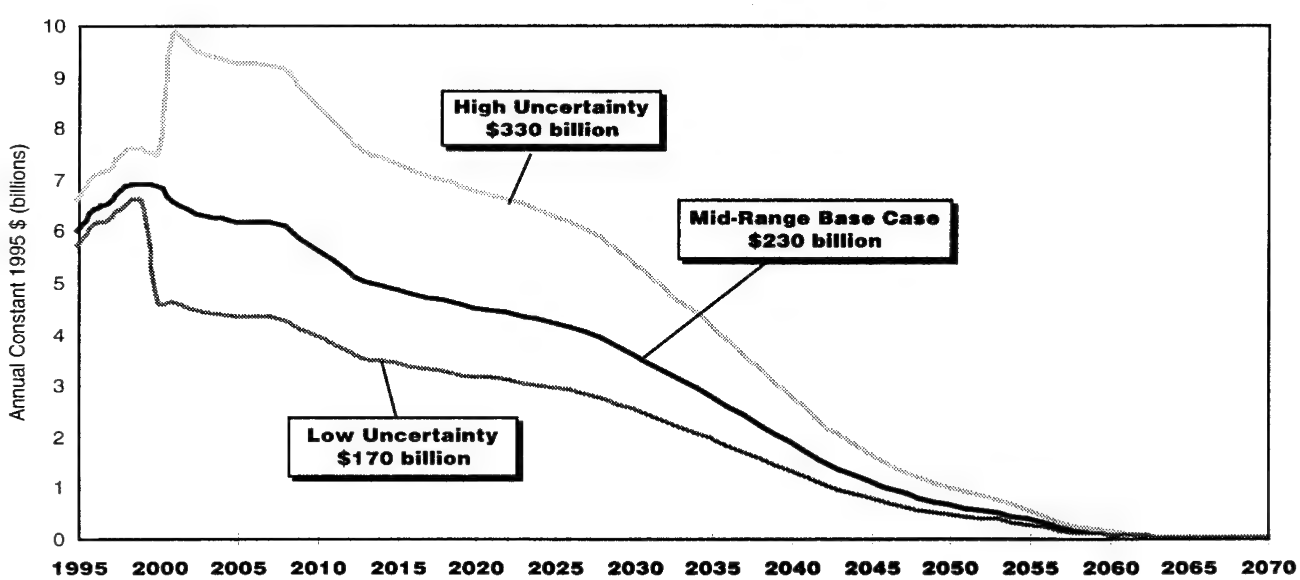


Figure 4.3. Uncertainty Range Surrounding the Mid-Range Base Case Estimate

(1) *American Association of Cost Engineers, Cost Engineers Notebook, Morgantown, WV, 1978. Cost Engineering Terminology Index No. AA-4,000 revised - 1/78.*

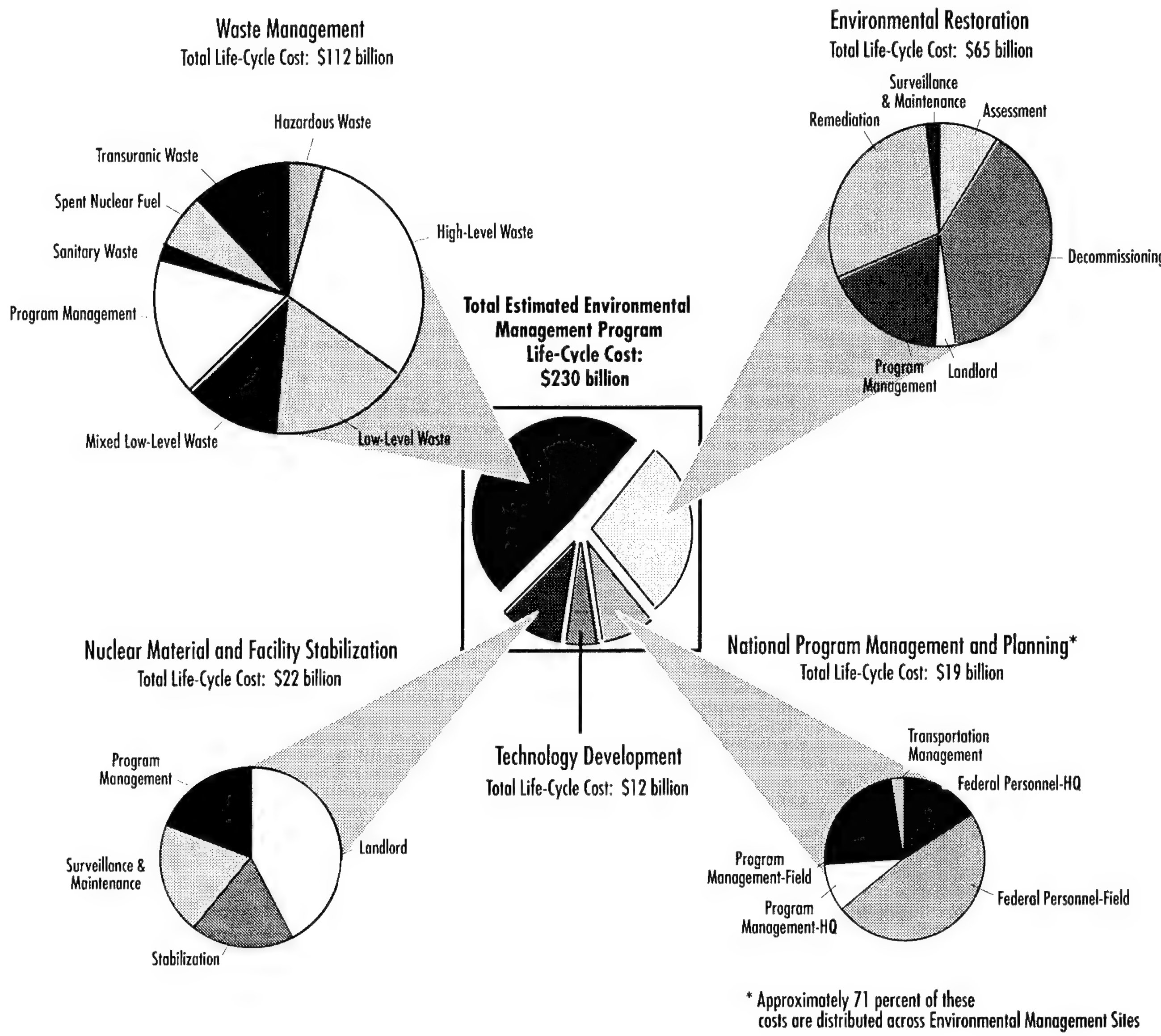


Figure 4.4. Mid-Range Base Case Estimate for Major Elements of the Environmental Management Program

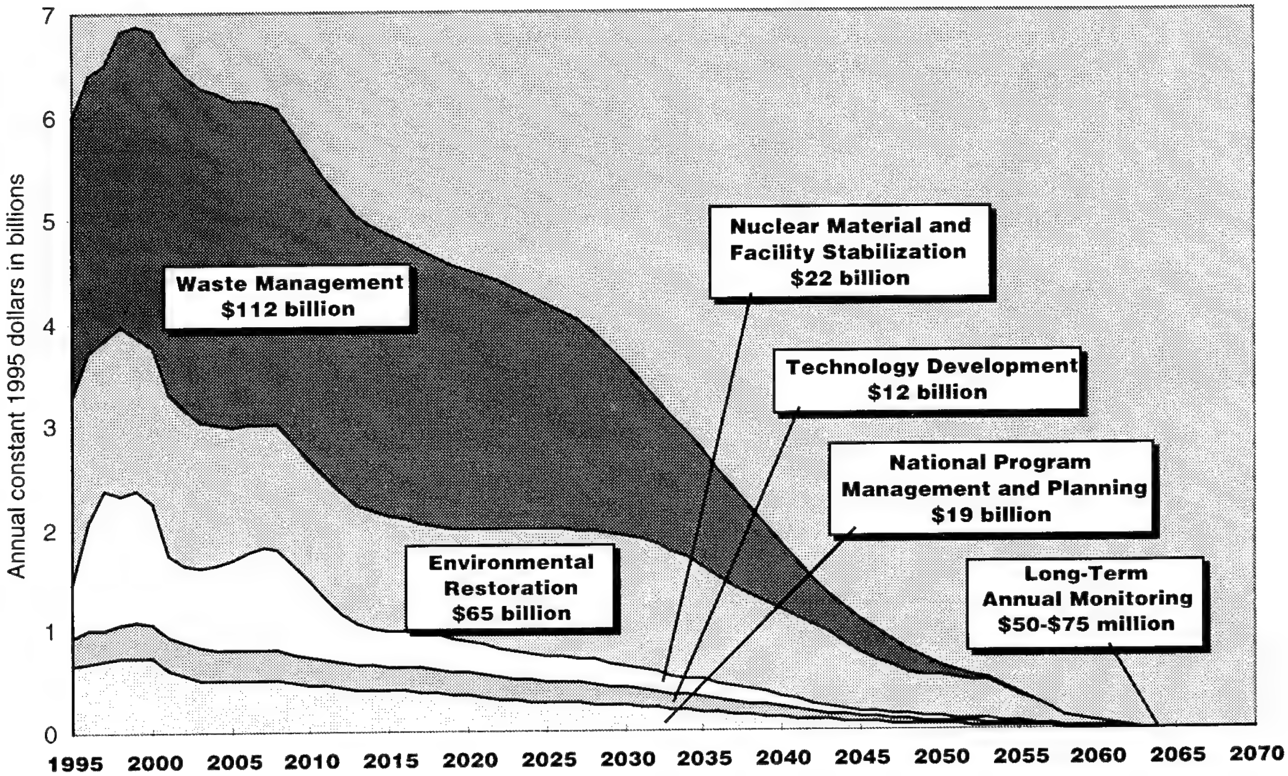


Figure 4.5. Mid-Range Base Case Cost Profile for Major Elements of the Environmental Management Program

amount to $34 billion or over 30 percent of the total waste management costs and approximately 15 percent of the total mid-range Base Case estimate. The spent nuclear fuel program totals $8 billion. The remaining costs of managing low-level waste, transuranic waste, low-level mixed waste, hazardous waste, and sanitary waste are $19 billion, $13 billion, $13 billion, $5 billion, and $2 billion, respectively, on a life-cycle cost basis.

A further breakdown of the waste management life-cycle costs in terms of treatment, storage, and disposal activities is depicted in Figure 4.6. Initially, the largest cost component is storage of wastes awaiting appropriate treatment and disposal. As treatment facilities are built and waste is processed, the storage costs decrease. The large increase in treatment costs up to a sustained peak from about the year 2005 to 2020 reflects the construction and operation of treatment facilities at several major sites (e.g., in response to the requirements of the Federal Facility Compliance Act). Disposal costs include operation of the Waste Isolation Pilot Plant for transuranic waste and currently operating low-level waste sites. Costs for disposal increase as waste is treated and low-level mixed waste disposal facilities are assumed to become available. Disposal costs significantly increase as the geologic repository becomes available for high-level waste disposal after the year 2016.

Environmental restoration is the next largest component (28 percent) of the total program estimate at $65 billion. The costs of remedial actions and decommissioning dominate the environmental restoration program; together they amount to $45 billion on a life-cycle basis and represent 69 percent of the total environmental restoration program. The assessment activities at the sites, which include the remedial

Table 4.2. Estimate of Costs for Selected Environmental Management Projects*

Project	Total Cost (Contant 1995 $ Millions)
Environmental Restoration	
Idaho National Engineering Laboratory Radioactive Waste Management Complex Remediation (Idaho)	$3,000
K-25 Site Decontamination and Decommissioning (Tennessee)	7,900
Savannah River Site H and F Canyon Remediation (South Carolina)	9,600
Waste Management	
Tank Waste Remediation System at Hanford (Washington)	29,000
Defense Waste Processing Facility at Savannah River Site (South Carolina)	4,000
West Valley Demonstration Plant (New York)	3,800
Waste Isolation Pilot Plant (New Mexico)	7,600
Nuclear Material and Facility Stabilization	
PUREX Plant (Washington)	270
Special nuclear material consolidation at Rocky Flats	80
Oak Ridge National Laboratory Isotopes Facilities	50

*Cost estimates for projects/activities are found in Volume II. Productivity savings are not included in these estimates because the savings are yet to be realized and may not be equally distributed across the project/activity level.

investigations and Resource Conservation and Recovery Act facility investigations, are $6 billion or 9 percent of the total environmental restoration program. The balance of the costs are for direct landlord responsibilities ($2 billion), surveillance and maintenance activities ($1 billion), and program management ($11 billion).

The third largest element of the Environmental Management program, the nuclear material and facility stabilization program, represents $22 billion or 10 percent of the total Environmental Management program. Although these activities are approximately 25 percent of the FY 1996 budget, the lower percentage over the life-cycle of the program reflects the assumption that many major facilities are deactivated and transferred to the restoration program for decommissioning by the year 2010, as reflected in Figure 4.5. Site landlord and program management activities combine to $14 billion with estimates of approximately $10 billion and $4 billion, respectively. Facility stabilization activities are $4 billion; surveillance and maintenance before stabilization are $4 billion; and surveillance and maintenance after stabilization are $0.2 billion.

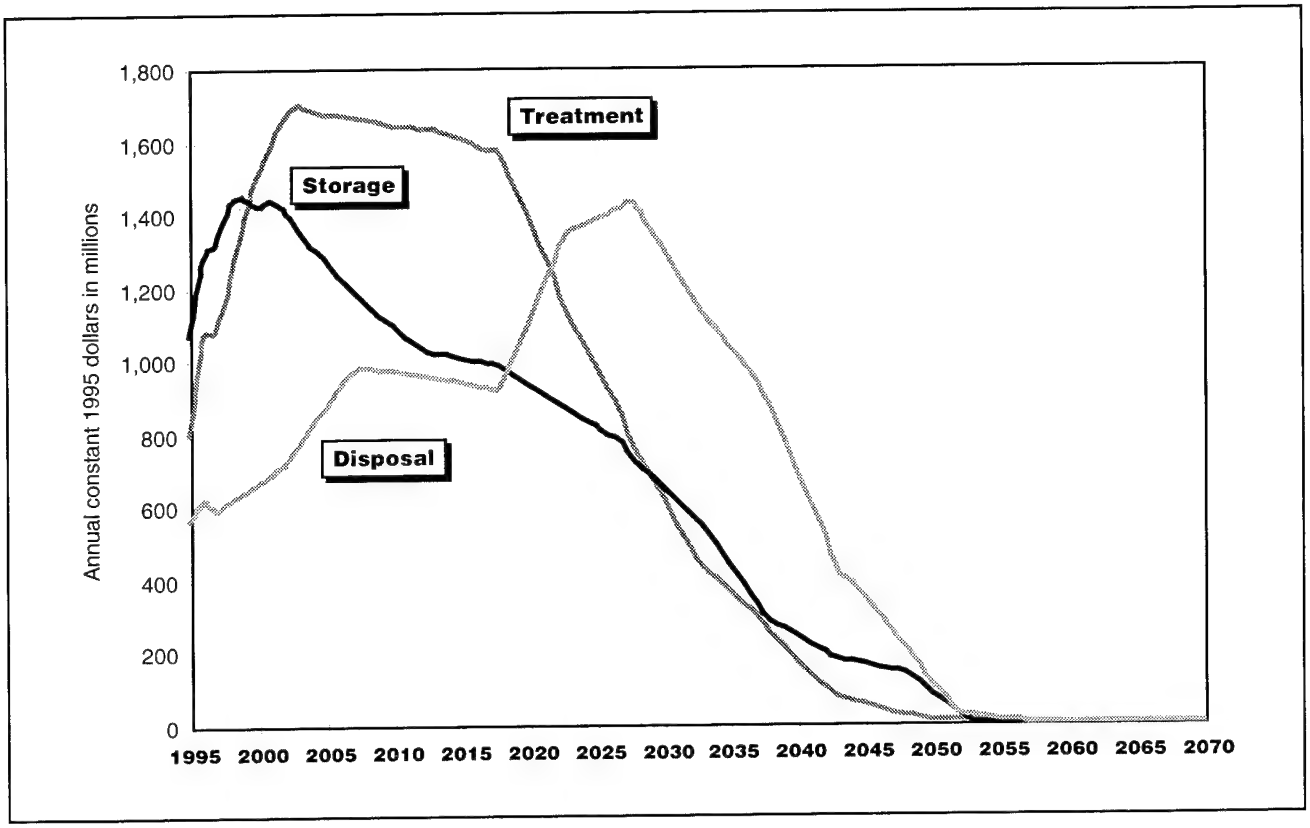


Figure 4.6. Annual Costs of Waste Treated, Stored, and Disposed by the Waste Management Program

National program management activities account for $19 billion of the mid-range life-cycle estimate. In the Baseline Report estimates, this category covers the cost for all (field and Headquarters) Federal personnel and analytical contractor support. Of the $19 billion in management activities, over $13 billion or 71 percent are distributed to the field operations in the form of Federal employees or analytical contractor support. The life-cycle cost estimate for these management activities includes $0.5 billion for the Department's coordination and management of transportation activities.

Savings from Waste Minimization

The projected future costs for providing waste management support for ongoing programs is $19 billion (see Section 4.5). Although it was not possible to quantify life-cycle cost savings from future waste minimization and pollution prevention activities, significant savings to this projected cost can also be expected from the waste minimization program that is being implemented throughout Environmental Management. This program already has resulted in significant savings. For example, in FY 1994, the pollution prevention program at Hanford saved nearly $44 million in disposal, product, and labor costs. It is reasonable to expect that waste reductions and cost savings could amount to several billion dollars over the life-cycle of the Environmental Management program.

The technology development program amounts to $12 billion or 5 percent of the total projected costs. These monies fund research and development programs on innovative technology applications for the Environmental Management program.

4.3 Base Case Estimate by State and Site

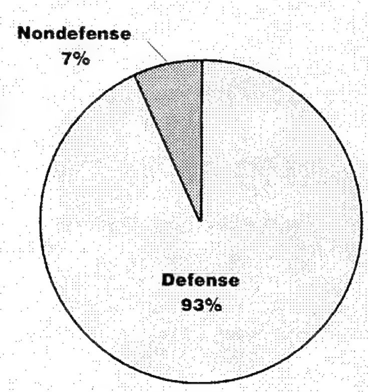
The projected life-cycle costs by State and by site are examined to understand more clearly where and when the mid-range Environmental Management life-cycle costs will be spent.

Table 4.3 shows projected life-cycle costs by State and the percentage by State of the cumulative life-cycle cost. Five out of the more than 30 States and territories examined in the 1995 Baseline Report (Washington, South Carolina, Tennessee, Colorado, and Idaho) account for $164 billion over the life of the Environmental Management program—71 percent of projected life-cycle costs (see Figure 4.7). Within these States are the major environmental management sites.

The projected program estimate is largely defined by environmental management activities within two States, Washington and South Carolina. Washington and South Carolina together account for $97 billion or 42 percent of projected life-cycle costs, which is consistent with the current Environmental Management budget (environmental management activities within the States of Washington and South Carolina account for 38 percent of the Environmental Management FY 1996 congressional budget request).

Projected Life-Cycle Costs by Congressional Appropriation

The Congressional Appropriations Subcommittee on Energy and Water appropriates funds to the Environmental Management program. These discretionary appropriations are divided into two accounts: (1) defense; and (2) nondefense. Environmental Management defense funding represents $214 billion or 93 percent of total costs. Environmental Management activities with a past defense mission, such as stabilizing the high-level waste at the Hanford Site, Washington, are appropriated under the defense account. On a life-cycle basis, nondefense activities represent $16 billion or 7 percent of the total projected life-cycle program cost. Environmental Management activities with a nondefense mission, such as the West Valley Demonstration Project, New York, are funded through nondefense appropriations. Environmental Management activities compete for funding against other activities under the jurisdiction of the Energy and Water Subcommittee, such as the Army Corps of Engineers (Civil), the Nuclear Regulatory Commission, and the Bureau of Reclamation (Department of the Interior).



Total Mid-Range Life-Cycle Cost = $230 billion

Within the States of Washington, South Carolina, Colorado, Tennessee, and Idaho are the 5 most costly Environmental Management sites—the Hanford Site (Washington), the Savannah River Site (South Carolina), the Rocky Flats Environmental Technol-

Table 4.3. Mid-Range Base Case Estimate by State and Site

Site	Mid-Range Base Case Cost (Constant 1995 $ in Millions)	Percentage of Total Mid-Range Base Case Cost
Alaska	***2***	***<1%***
Nevada Offsite* - Alaska	2	<.01%
Arizona	***139***	***<1%***
Completed UMTRA S&M** - Arizona	139	0.06%
California	***2,273***	***0.98%***
Energy Technology Engineering Center	249	0.11%
General Atomics	12	0.01%
General Electric Vallecitos Nuclear Center	18	0.01%
Geothermal Test Faciity	6	<.01%
Laboratory for Energy Related Health Research	34	0.01%
Lawrence Berkeley Laboratory	208	0.09%
Lawrence Livermore National Laboratory	1,521	0.66%
Oxnard	13	0.01%
Sandia National Laboratories - Livermore	92	0.04%
Stanford Linear Accelerator Center	119	0.05%
Colorado	***23,294***	***10.10%***
Completed UMTRA S&M - Colorado	7	<.01%
Grand Junction Project Office Site	707	0.31%
Gunnison	14	0.01%
Maybell	23	0.01%
Naturita	26	0.01%
Rifle	34	0.01%
Rocky Flats Environmental Technology Site	22,455	9.74%
Nevada Offsite - Colorado	3	<.01%
Slick Rock	26	0.01%
Connecticut	***3***	***<.01%***
FUSRAP*** - Connecticut	3	<.01%
Florida	***189***	***<1%***
Pinellas Plant	189	0.08%
Idaho	***18,658***	***8.09%***
Argonne National Laboratory - West	229	0.10%
Completed UMTRA S&M - Idaho	<1	<.01%
Idaho National Engineering Laboratory	18,430	7.99%
Illinois	***612***	***<1%***
Argonne National Laboratory - East	527	0.23%
Fermi National Accelerator Laboratory	76	0.03%
FUSRAP - Illinois	1	<.01%
Site A/Plot M	8	<.01%
Iowa	***12***	***<1%***
Ames Laboratory	12	0.01%
Kentucky	***3,390***	***1.47%***
Maxey Flats	221	0.01%
Paducah Gaseous Diffusion Plant	3,368	1.46%
Maryland/District of Columbia	***30,143***	***13.07***
FUSRAP - Maryland	7	<.01%
Environmental Management Headquarters****	30,136	13.07%
Massachusetts	***14***	***<1%***
FUSRAP - Massachusetts	14	0.01%
Michigan	***1***	***<1%***
FUSRAP - Michigan	1	<.01%
Mississippi	***3***	***<1%***
Nevada Offsite - Mississippi	3	<.01%
Missouri	***1,074***	***0.47%***
FUSRAP - Missouri	388	0.17%
Kansas City Plant	312	0.14%
Weldon Spring Site Remedial Action Project	373	0.16%

*Nevada Offsite are locations where nuclear detonations occurred and environmental management activities are managed by the Nevada Operations Office.
** UMTRA S&M is the acronym for Uranium Mill Tailings Remedial Action projects with long-term Surveillance and Maintenance activities.
***FUSRAP is the acronym for the Formerly Utilized Sites Remedial Action Program.
****Approximately 71 percent of these costs are distributed across Environmental Management sites.

Table 4.3. Mid-Range Base Case Estimate by State and Site (contd.)

Site	Mid-Range Base Case Cost (Constant 1995 $ in Millions)	Percentage of Total Mid-Range Base Case Cost
Nebraska	***<1***	***<1%***
Hallam Nuclear Power Plant	<1	<.01%
Nevada	***2,472***	***1.07%***
Nevada Test Site	2,443	1.06%
Nevada Offsite - Nevada	29	0.01%
New Jersey	***440***	***<1%***
FUSRAP - New Jersey	322	0.14%
Princeton Plasma Physics Laboratory	118	0.05%
New Mexico	***9,647***	***4.18%***
Albuquerque Operations Office	456	0.20%
Ambrosia Lake	<1	<.01%
Completed UMTRA S&M - New Mexico	3	<.01%
Inhalation Toxicology Research Institute	19	0.01%
Los Alamos National Laboratory	3,304	1.43%
Nevada Offsite - New Mexico	10	<.01%
Sandia National Laboratories - New Mexico	890	0.39%
South Valley Site	18	0.01%
Waste Isolation Pilot Plant	4,948	2.15*
New York	***4,003***	***1.74%***
Brookhaven National Laboratory	460	0.20%
FUSRAP - New York	273	0.12%
Separations Process Research Unit	112	0.05%
West Valley Demonstration Project	3,157	1.37%
North Dakota	***22***	***<1%***
Belfield/Bowman	22	0.01%
Ohio	***11,743***	***5.09%***
Battelle Columbus Laboratories	110	0.05%
Fernald Environmental Management Project	4,186	1.82%
FUSRAP - Ohio	197	0.09%
Mound Plant	1,539	0.67%
Piqua Nuclear Power Plant	<1	<.01%
Portsmouth Gaseous Diffusion Plant	5,575	2.42%
Reactive Metals, Inc.	135	0.06%
Oregon	***3***	***<1%***
Completed UMTRA S&M - Oregon	3	<.01%
Pennsylvania	***3***	***<1%***
Completed UMTRA S&M - Pennsylvania	3	<.01%
South Carolina	***48,174***	***20,90%***
Savannah River Site	48,174	20,90%
Tennessee	***24,812***	***10.76%***
Oak Ridge Y-12 Site	4,127	1.79%
Oak Ridge Reservation	277	0.12%
Oak Ridge K-25 Site	12,662	5.49%
Oak Ridge Associated Universities	18	0.01%
Oak Ridge National Laboratory	7,729	3.35%
Texas	***582***	***<1%***
Completed UMTRA S&M - Texas	21	0.01%
Pantex Plant	562	0.24%
Utah	***140***	***<1%***
Completed UMTRA S&M - Utah	8	<.01%
Monticello Millsite and Vicinity Properties	131	0.06%
Washington	***48,671***	***21.11%***
Hanford Site	48,671	21.11%
Wyoming	***25***	***<1%***
Completed UMTRA S&M - Wyoming	25	0.01%
Total	**$230 Billion**	**100%**

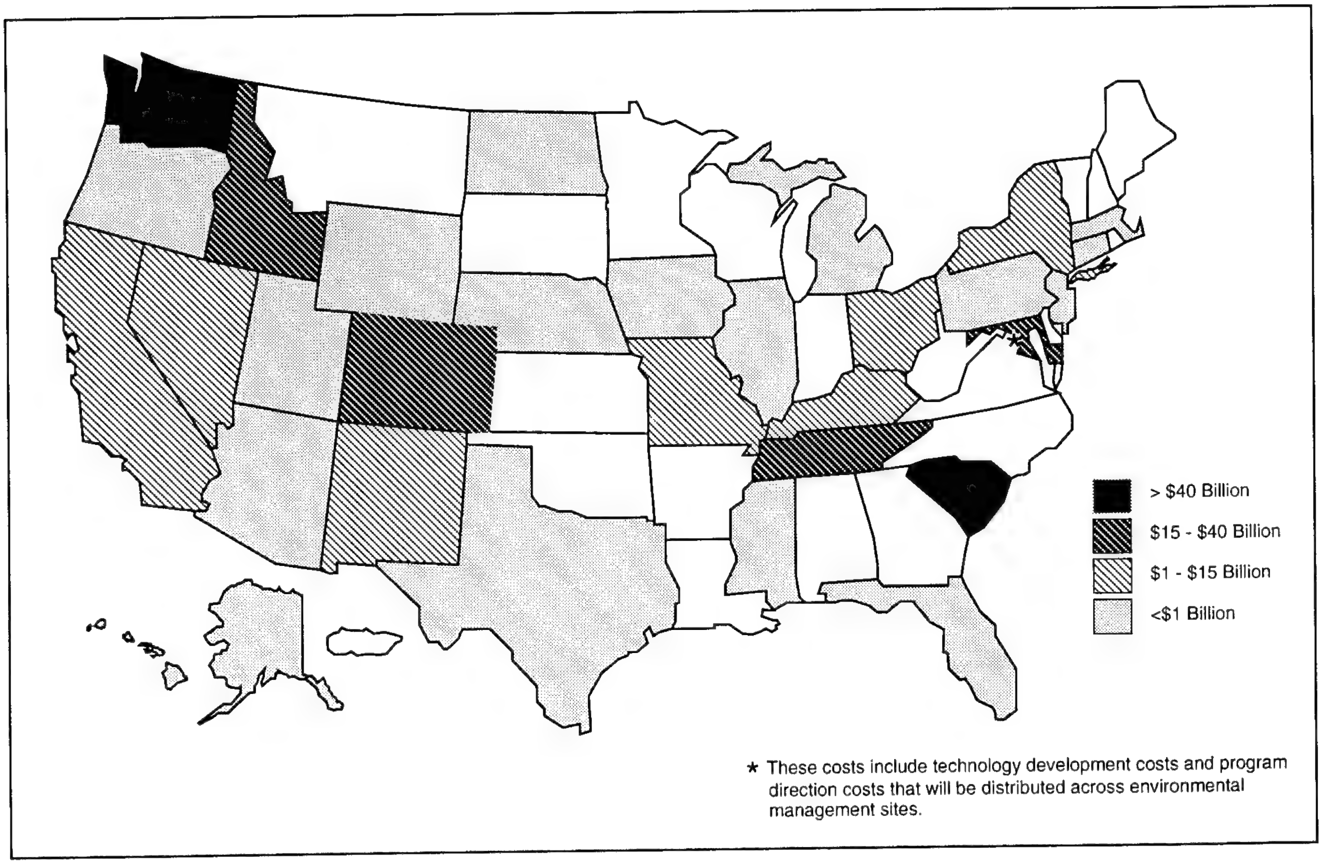


Figure 4.7. Mid-Range Base Case Estimate by State

ogy Site (Colorado), the Oak Ridge Reservation [including the K-25 Site, the Y-12 Plant, and the Oak Ridge National Laboratory (Tennessee)], and the Idaho National Engineering Laboratory (Idaho). Table 4.3 displays the projected total life-cycle costs by site and the percentage by site of the cumulative life-cycle cost. Consistent with the projected costs by State, these 5 sites—out of the 115 sites examined in the 1995 Baseline Report—account for 71 percent of the total program estimate (see Figures 4.8, 4.9, and Table 4.3). Consistent with the projected total costs by State, the mid-range Base Case estimate is largely defined by the activities at two sites, the Hanford Site in Washington and the Savannah River Site in South Carolina.

At the Hanford Site, Washington, estimated waste management costs represent about 75 percent of the Environmental Management mid-range life-cycle cost estimate, half of which is required for the treatment, storage, and disposal of high-level waste.

At the Savannah River Site, the majority of costs are associated with constructing or upgrading treatment and storage facilities for high-level waste and spent nuclear fuel. Also, decontaminating and dismantling more than 100 facilities contaminated with radioactive and hazardous chemicals and remediating contaminated ground water significantly increases costs.

Based on Base Case funding assumptions, the Environmental Management program extends about 75 years, with the majority of environmental management ac-

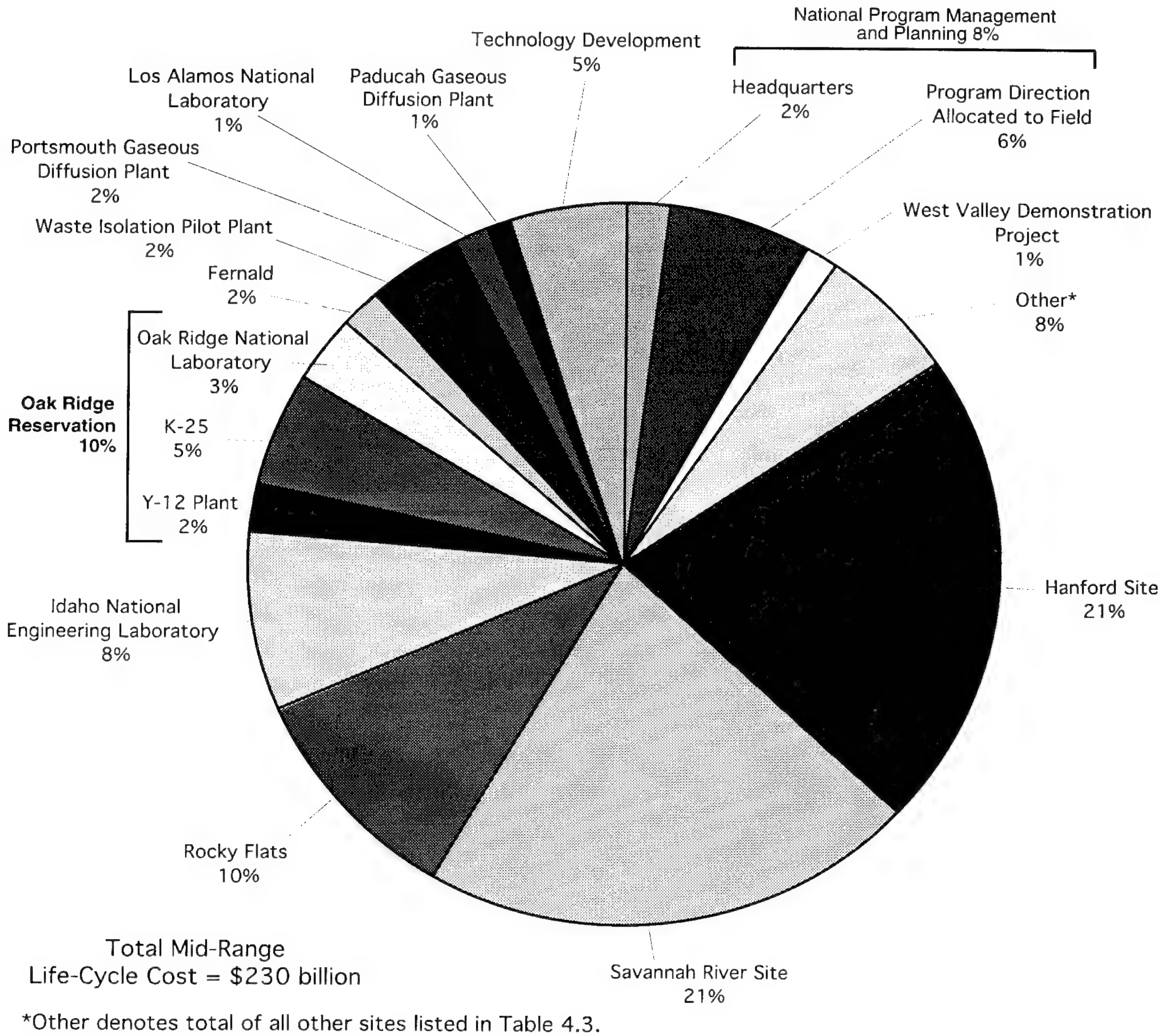


Figure 4.8. Mid-Range Base Case Estimate by Site

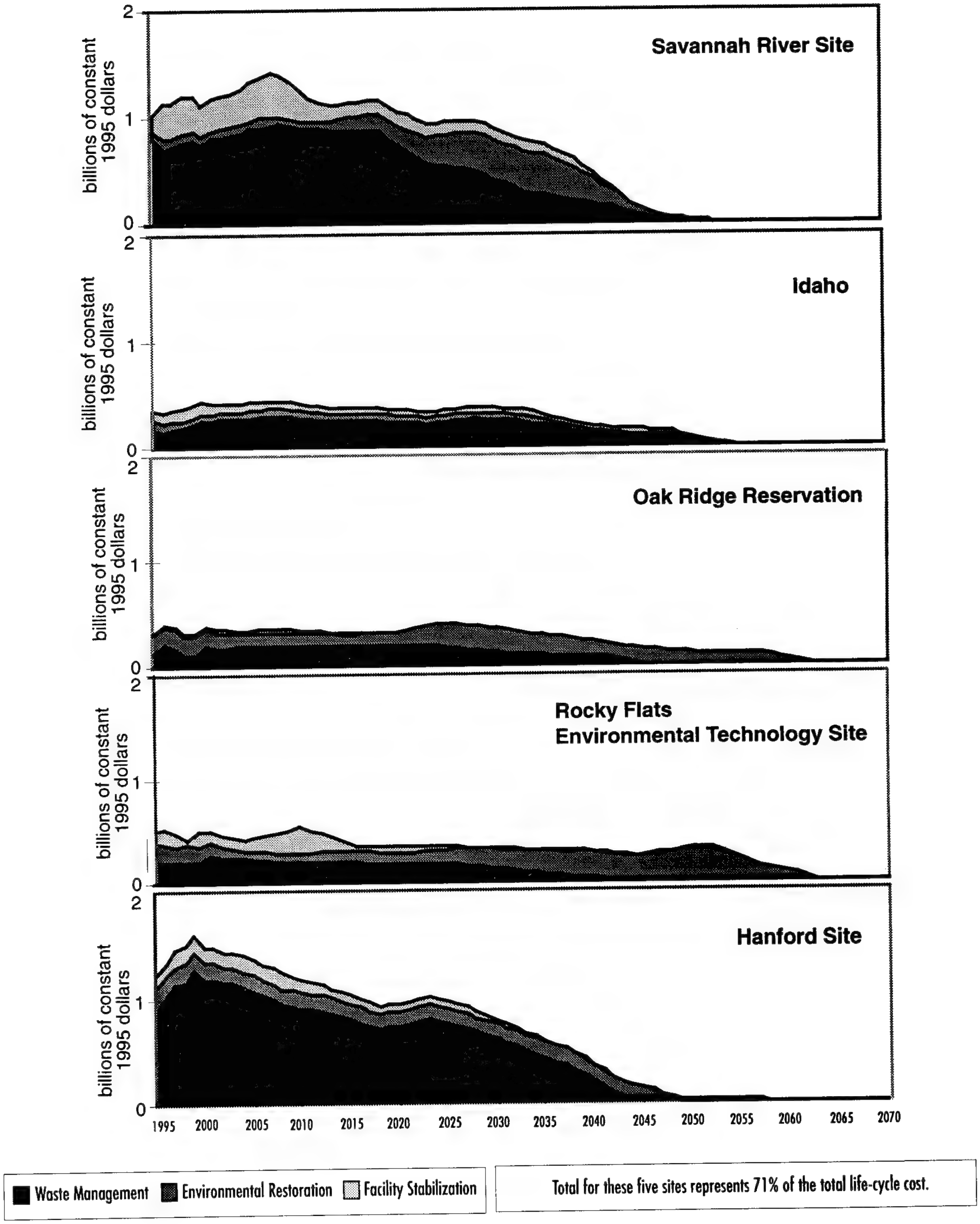


Figure 4.9. Mid-Range Base Case Cost Profiles for the Five Largest Sites

tivities ending in about FY 2070. However, limited activities at some major environmental management sites extend beyond this date because of the costs of long-term surveillance and maintenance activities, such as maintaining containment barriers and periodic ground-water sampling and support of ongoing operations.

4.4 Costs of Activities Supporting the Environmental Management Program

Previous sections describe the activities and costs most often thought of as "environmental management" such as remediating contaminated areas and treating, storing, and disposing of radioactive and hazardous wastes. Other functions, known as "support" activities, although not considered direct environmental efforts, are integral to ensuring the mission is accomplished, and therefore, must be included in an estimate of the cost of the Environmental Management program. The costs of support functions associated with field operations and Headquarters activities are described below.

4.4.1 Field Support Costs

For cost-estimating purposes, field support activities were divided into three categories: landlord, program management, and site-wide support. The first two categories—program management and landlord—are discreet cost categories, often referred to as "direct funded." It is easy to highlight these costs as distinct activities (see Figure 4.4). The third category, site-wide support, is not a discreet cost category, and is referred to as an "indirect" cost. These indirect costs are not highlighted as separate costs in this report; rather, they are included in the total life-cycle costs for the waste management, environmental restoration, and material stabilization programs (see Figure 4.4).

Landlord

As discussed in Section 2.3.5, the Environmental Management program is or will soon be landlord at 10 installations. At these sites, the Environmental Management program both oversees and directly pays for site-wide infrastructure support. Over the lifetime of the program, the direct-funded landlord costs are estimated to be \$11.5 billion or 5 percent of the total projected cost estimate. As shown in Figure 4.4, approximately \$2 billion of these costs are managed in conjunction with environmental restoration activities at the K-25, Fernald, and Grand Junction sites. The remaining costs are managed under the nuclear material and facility stabilization program.

Program Management

The size of the installations and complexity of the work in progress mandate that effective management controls are in place to ensure worker safety, environmental compliance, and sound project management. The field "program management" cost category provides for these management controls, as well as other activities such as grants to States and localities. Volume II site summaries report program

management activities separately at each installation—describing activities specific to the installation. Over the lifetime of the program, field program management is estimated to cost $34 billion or 15 percent of the total mid-range Base Case estimate.

Site-Wide Support Functions

Site-wide support activities are administrative in nature and benefit all programs at an installation. They include human resources, financial offices, procurement, legal, logistics support, administrative support, quality assurance, taxes, information services, environmental safety and health, facilities management and engineering and maintenance, public information and outreach, safeguards and security, utilities, executive direction, fee, and research and development. The approximate distribution of site-wide support costs is provided in Figure 4.10. Across all activities, Environmental Management will pay approximately $46 billion to fund site-wide support activities over the life of the program. These costs represent 20 percent of the total mid-range life-cycle cost estimate.

4.4.2 Headquarters Support Costs

The program activities managed at Headquarters can be considered "support costs" because they are not direct environmental missions, but are integral to management of the Federal program. For cost-estimating purposes, the assumption was made that support costs originating at Headquarters would continue to be estimated as such. The national accounts of program direction, program man-

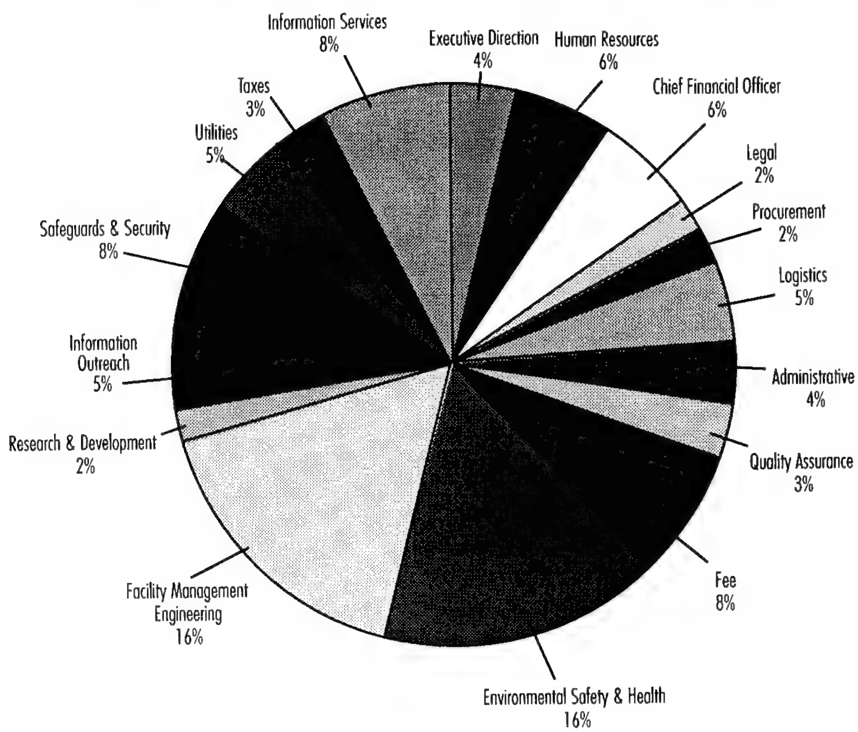


Figure 4.10. Distribution of Site-Wide Support Costs

agement, and transportation management all have their origins at Headquarters. However, it is misleading to attribute all expenditures to Headquarters because the majority of the funds are eventually allocated to the field. The following sections describe these accounts and their relative distribution to field operations.

Program Direction (Federal Personnel)/Program Management (Contractor Analytical Support)

The program direction account funds all Federal full-time equivalents at Headquarters and field offices, including salaries, benefits, and training. Approximately 75 percent of this account is reallocated to field operations. The total life-cycle cost assumes $12 billion for program direction over the life of the program. Program Management activities provide technical contractor support services for all elements of the Headquarters-directed activities. Approximately 70 percent of this account is transferred to field operations. The total life-cycle costs assume $6 billion for program management over the life-cycle of the program.

Transportation Management

The transportation program provides for Department-wide development and implementation of effective strategies, techniques, methods, and policy guidance for safe, secure, efficient transportation of Department of Energy materials. These materials include general commodities (coal construction materials, recyclables, etc.), hazardous materials, spent fuel, radioactive and hazardous wastes, and special nuclear materials. Approximately 95 percent of these funds are transferred to field operations to develop agency-wide logistics management tools, training, and technology to address Department transportation and packaging requirements. The total life-cycle cost assumes $0.5 billion for transportation management over the life-cycle of the program.

4.5 A Closer Look at the Cold War Mortgage

Most of the life-cycle costs for the Environmental Management program address wastes that have been generated or facilities or areas contaminated in the process of producing nuclear weapons. Although the environmental costs of the weapons legacy are large, Environmental Management also addresses a legacy of waste from nonweapons programs as well as wastes generated by ongoing activities. To evaluate their respective cost impacts, Environmental Management activities were divided into the following three categories:

- *Nuclear weapons legacy waste costs* encompass environmental activities that remediate sites in the weapons complex or address stored legacy wastes from weapons research, design, and production. These costs also include activities for stabilizing and decommissioning excess facilities, or portions of facilities, attributable to the weapons program (see Figure 4.11). Weapons-legacy waste accounts for approximately $172 billion, mid-range Base Case of the cost estimate or about 75 percent of the cost of the Environmental Management program.

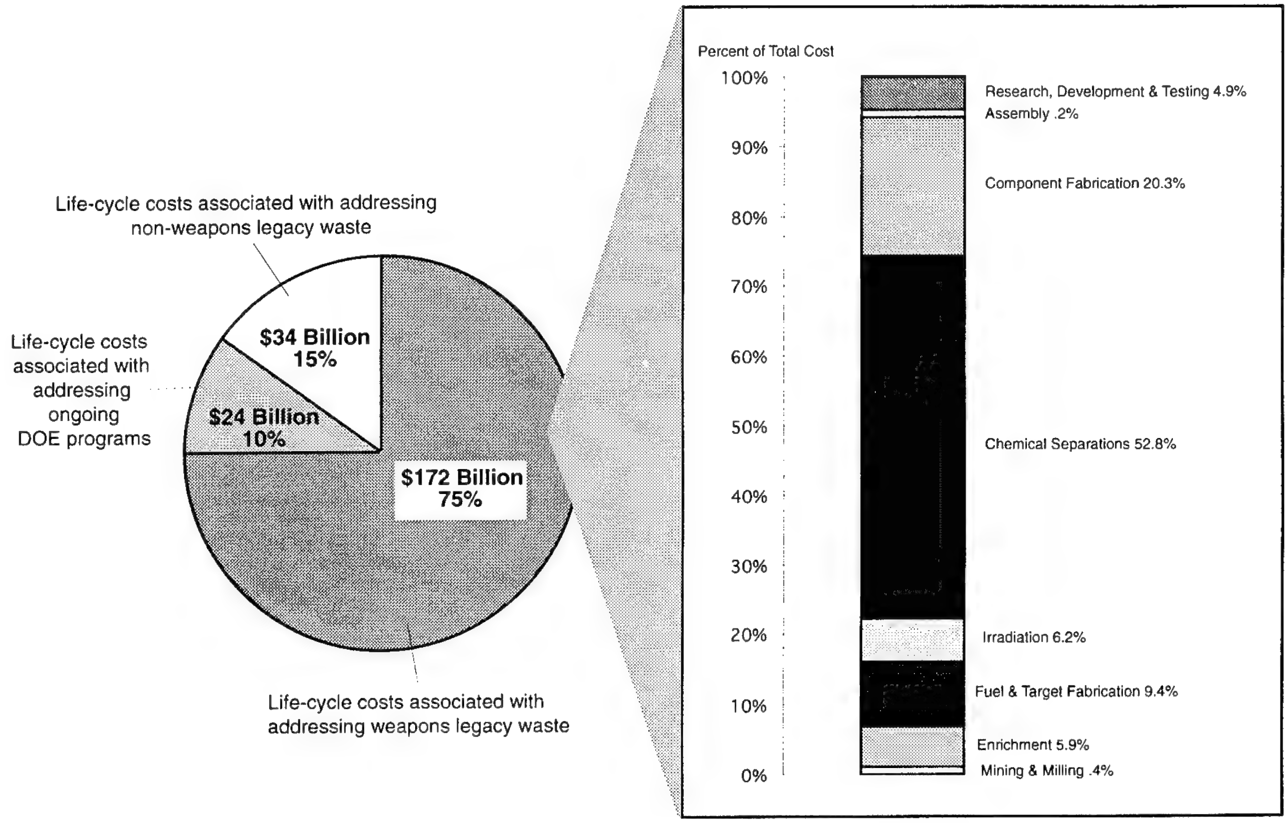


Figure 4.11. Contributions of the Weapons Legacy to the Environmental Management Total Life-Cycle Cost

- *Nonweapons legacy waste costs* are those associated with cleaning up waste generated in the past in activities not specifically linked to nuclear weapons production, such as energy research, basic science, and the Three Mile Island accident. The total life-cycle costs associated with nonweapons legacy amount to $34 billion or approximately 15 percent of the total life-cycle cost.

- *Ongoing program costs* are costs necessary to manage all future waste streams. The projected cost of treatment, storage, and disposal of waste generated by ongoing defense and research activities is $19 billion. In addition to the environmental costs of future waste, this category also includes a portion of landlord costs for operating and maintaining sites.

Weapons legacy costs can be further divided into costs from the eight major nuclear weapons production steps, which were summarized in Chapter 2 and are detailed in Appendix B. The life-cycle environmental costs associated with each of these steps can be estimated by examining the legacy waste at those sites where any one or more of these nuclear weapons production activities were conducted. For example, the Portsmouth Gaseous Diffusion Plant was dedicated to uranium enrichment. Other sites had multiple weapons production steps, such as the Hanford Site, Washington (e.g., fuel fabrication, irradiation, chemical separation).

Chemical separation is seen to be, by far, the most costly step in terms of life-cycle environmental management costs. During this step, chemical separation plants, called "canyons," recovered plutonium and uranium from irradiated fuel and targets. These plants generated millions of gallons of highly radioactive and hazardous chemical wastes, which were stored in tanks. Billions of gallons of contaminated waste water also were generated and for many years were discharged directly into the ground. The environmental management costs for this step alone represent over 53 percent or $91 billion of the total mid-range Base Case program cost for weapons legacy waste. The share of environmental costs attributable to other weapon process steps is shown in the figure.

4.6 Comparison of Results to the Department's Previous Cost Estimate

The estimate of the total cost of the Environmental Management program presented in this report is substantially higher than the Department's previous total cost estimate.[1] In 1988, the Department estimated a total cost of $91-130 billion to meet its environment, safety, and health needs, primarily during a 20-year time period. This equates to $109-156 billion in constant FY 1995 dollars. Using the same metric, the total cost estimate in this Baseline Report (unadjusted for productivity gains) is $350 billion, or two to three times greater than the 1988 estimate. Table 4.4 compares these two cost estimates.

The total cost estimate in this Baseline Report reflects a profound change in the mission, activities, and land-use goals at Department of Energy installations resulting from the end of the Cold War. The 1988 cost estimate was made when the primary concern was to bring the Department's installations into compliance with environmental regulations to allow continued weapons production. Environmental management activities reflected in the 1988 estimate focused on activities such as permitting, installation, and operation of air and water monitoring systems and some corrective actions at active sites. Little emphasis was placed on more expensive activities such as facility decommissioning and waste treatment. The end of the Cold War resulted in a shift from production to cleanup.

The comparison in Table 4.4 reflects this shift in priorities. The estimated cost for decommissioning is 10 times greater in this report than in the 1988 report, and this report includes $14 billion in facility stabilization costs that were not included in the 1988 report. These differences reflect the greater number of production and research facilities that now are considered surplus. In contrast, the 1988 report includes $34-42 billion in costs for corrective and other actions to bring weapons production facilities into compliance with environmental laws and regulations and to continue to operate these facilities, while these activities are largely completed or unnecessary now that production has ceased.

The estimated cost for waste management activities is nearly five times greater in this report than in the 1988 report. This higher cost estimate reflects a more comprehensive understanding of the volumes and nature of wastes present in the complex and the amount of treatment that will be necessary than was available for

(1) U.S. Department of Energy. 1988. *Environment, Safety, and Health Needs of the U.S. Department of Energy, Volume 2: Site Summaries*, DOE/EH-0079. Washington, D.C.

Table 4.4. Comparison of Cost Estimates in 1988 Needs Report and 1995 Baseline Report (values in billions of constant 1995 dollars)

Activity Category	1988 [1]	1995 [2]	Comparison
Environmental restoration			The 1995 estimate for remedial actions is somewhat comparable to the lower bound of the 1988 estimate because both place greater emphasis on containment versus active remediation strategies. The scope of decommissioning activities is much greater in the 1995 estimate because the 1988 report assumes that most facilities will continue to have a nuclear weapons production mission.
Assessment	2-4	8	
Remedial actions	39-73	29	
Decommissioning	4-6	45	
Total	45-83	82	
Waste Management			In the 1988 report, mixed waste had not yet been defined as a category, very little waste treatment was assumed, costs for waste management generally were not included beyond 2010, and some high-level waste costs are included in other categories (e.g., remedial actions).
High-level waste	20-21	60	
Transuranic waste	3	17	
Other wastes	7	66	
Total	30-31	143	
Facility stabilization	___	14	The 1988 report assumes that most facilities will continue to have a nuclear weapons production mission; therefore, the number of surplus facilities is much greater in the 1995 report. The 1988 estimate for decommissioning activities includes stabilization.
Technology development	___	17	The 1988 report includes some technology development in other categories, particularly environmental restoration and waste management.
Support activities			The 1988 report does not explicitly include support costs such as directly funded landlord, program management, and program direction.
Landlord	___	24	
Program direction/management	___	70	
Total	___	94	
Environmental safety & health			The 1988 report includes corrective actions to bring production facilities and infrastructure into compliance with existing environmental, health, and safety laws, regulations, and directives. These activities are not included explicitly in the 1995 report (many have been completed), although similar activities may be included in landlord activities.
Ongoing operations	25	___	
Corrective actions	9-17	___	
Total	34-42	___	
Grand Total	109-156	350	

[1] 1988 cost estimates (in constant 1990 dollars) were inflated to constant 1995 dollars using 1.2 as a multiplier.

[2] 1995 cost estimates are not adjusted for productivity.

the previous cost estimate. The 1988 estimate was made when information on the nature and extent of environmental problems was sketchy. The more comprehensive information available for this report, including current waste inventories, reflect the greater amount of information available as the result of site characterization efforts since 1988.

The higher total cost estimate presented in this report also reflects a more comprehensive methodology. This report includes support costs such as landlord and program management that were not within the scope of the 1988 cost estimate. In addition, the 1988 report assumed that most environmental management activities will be completed by 2020, while this report assumes that most activities will continue until approximately 2070.

5.0 Alternative Cases

This section describes several analyses looking at the effort of changing the assumptions regarding:

- *Land use*—What are the ultimate uses for currently contaminated lands, waters, and structures at each installation?
- *Program funding and scheduling*—How might activities be prioritized, and how rapidly will money be spent?
- *Technology development*—How might future technologies influence the Environmental Management program?
- *Waste management configuration*—Should treatment, storage, and disposal be carried out in a decentralized, regionalized, or centralized manner?

The Base Case used assumptions derived largely from field locations regarding the outcomes of various decisionmaking processes that will determine the scope and pace of the Environmental Management program and the ultimate disposition of Department of Energy facilities and installations. The final cost and schedule for the program will depend largely on departmental management decisions and compliance requirements under various environmental laws such as Superfund. Ultimately, the rate at which Congress appropriates funds also will determine final cost and schedule.

To help inform the national policymaking as well as local decisionmaking processes, a rigorous and objective analysis of life-cycle cost and schedule as well as the potential magnitude of these effects was needed. This section reports on analyses conducted for the four general areas listed above where future decisions or developments were felt to have significant impact on total program cost and schedule.

The approach used to develop and estimate costs to answer these questions differed from that used for the Base Case. Although the Base Case was developed using primarily field estimates and assumptions, the alternative cases were developed using a standardized modeling approach. The primary reason for this shift in strategy is that tools and data sources used to develop the Base Case were not adequate for evaluating alternative cases (e.g., detailed site-specific baselines and other bottom-up estimation techniques are not easily redone with alternative assumptions).

These four decision areas represent a partial list of factors that may affect total program cost. For example, different residual contamination standards—cleanup levels—for soil, water, and other media are thought to influence costs of remediation activities. An attempt was made to establish the variation in costs associated with different residual contamination levels. However, more information must be collected, and analyses need to be conducted before costs can be quantified nation-wide. Future analyses will evaluate the cost consequences of these and other factors as they are identified.

5.1 Land Use

The Department has begun working with stakeholders and regulators regarding the ultimate disposition of lands currently managed by the Department of Energy. Land-use decisions, which determine both the type and extent of site remedial approaches, will be a significant variable in the ultimate cost of the Environmental Management program. For example, containing contamination at a site may be sufficient for land that will remain restricted (i.e., off limits to human activity), while removal may be required for unrestricted land use. The range of costs associated with differing land-use scenarios is substantial. To illustrate the significance of future land-use decisions, the Department examined how total program cost would vary assuming a range of alternative future land uses.

Figure 5.1 depicts a continuum of future land uses ranging from completely restricted or controlled access to completely unrestricted or residential use. Four cases were developed for comparison with the Base Case cost estimate. Two cases illustrate the extreme opposite ends of the land-use spectrum. The "Iron Fence" case, based exclusively on containment strategies, represents the most restrictive land use. The "Maximum Feasible Green Field" case, based on removal of contamination, provides for essentially unrestricted land use. Two other cases, referred to as "Modified Containment" and "Modified Removal," illustrate what were judged to be more reasonable alternatives, taking into account existing legal obligations and departmental commitments that were reflected in the Base Case.

The costs for all four scenarios were estimated using a relatively simple computer model. This model used unit activity costs derived from experience at several of the Department's larger sites as well as nongovernmental cleanup projects. The scenarios are highly idealized and involve several simplifying assumptions to produce rough complex-wide estimates.

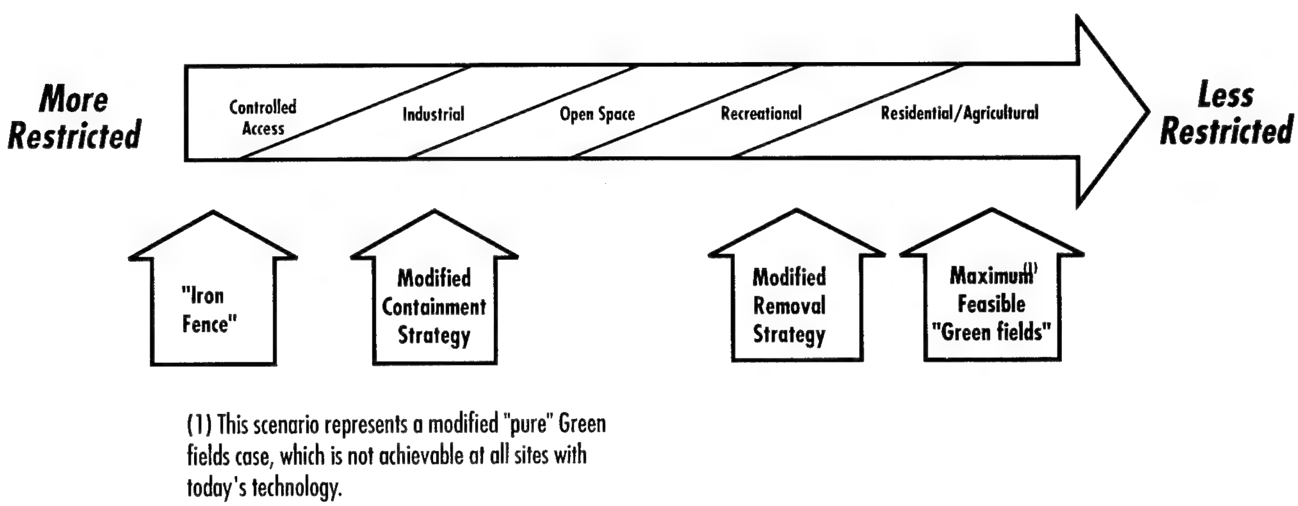


Figure 5.1. Conceptual Illustration of the Land-Use Continuum

5.1.1 Base Case Assumptions

The Department has begun integrating future land-use planning at its sites to guide environmental remediation goals. Since these efforts are under way, final land-use determinations have not been made at many of the Department's sites, particularly large sites with complex missions. Nonetheless, preliminary determinations or assumptions were made to prepare the Baseline Report.

The Base Case cost estimate was built on site-specific assumptions regarding future land use(s) at each installation or for a particular part of an installation. Land-use decisions are made or influenced by a number of different processes and situations, including:

- where a Record of Decision under the Comprehensive Environmental Resource, Compensation, and Liability Act process, contractual agreement, or other legally binding decision document has been signed;
- where an installation is not owned by the Department of Energy, and a contractual agreement dictates cleanup standards or future land use;
- where the Department has committed to release an installation for specific uses;
- where the Department has ongoing or planned disposal activities; and
- where remediation is not technologically possible.

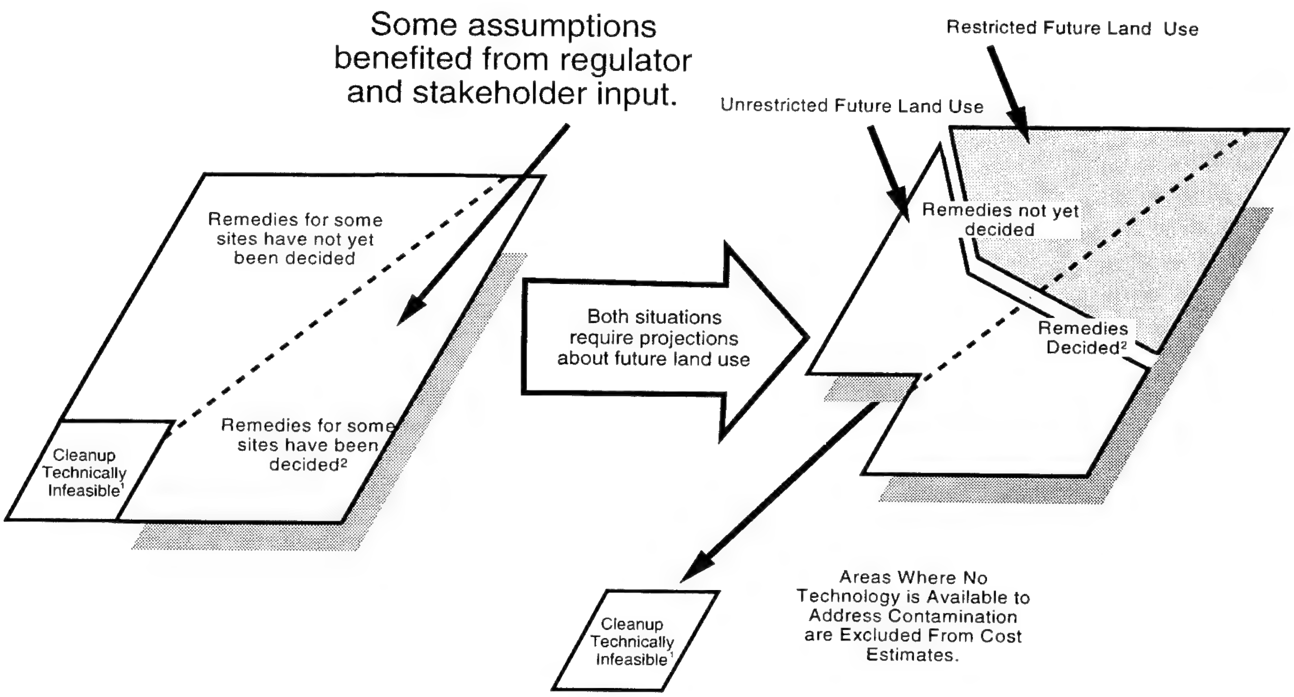
These decision processes and situations guided field program managers in creating the Base Case estimate. The Base Case incorporates decisions that have been made or anticipated outcomes of these processes.

Future land use in the Base Case varies from restricted use to unrestricted use. At the Department's smaller facilities, such as the Mound Site in Ohio or the Pinellas Plant in Florida, where contamination is assumed to be contained in place, future use would be limited to industrial purposes. Sites not owned by the Department or sites near heavily populated areas or water sources are generally assumed to be released for either residential use or industrial use. Examples include the General Atomics Site at La Jolla, California, and Battelle Columbus Laboratories in Columbus, Ohio.

Restricted land use is assumed for designated areas associated with ongoing disposal activities at six sites—the Hanford Site, the Idaho National Engineering Laboratory, Savannah River Site, Nevada Test Site, Oak Ridge Reservation, and the Los Alamos National Laboratory. In addition, restricted land use was assumed at the proposed deep geologic repository for transuranic waste—the Waste Isolation Pilot Plant. Finally, restricted land use was assumed at release sites that could not be remediated to risk levels associated with unrestricted use using current technologies. Prime examples of such sites are where ground water is contaminated with tritium, for which no removal technology is available, and nuclear explosion test areas like the Nevada Test Site with deep underground soil contamination.

In cases not bound by legal obligations or departmental commitments, future land use is less clear. This is particularly true for large sites, which are anticipated to incorporate a range of future land uses across the site. For example, at the Hanford Site, certain areas near the Columbia River are assumed to be remediated for unre-

stricted use. However, to accomplish this goal, contamination is to be moved to a disposal site away from the river. The disposal area is then assumed to remain indefinitely restricted. Figure 5.2 illustrates a mixed land-use concept for a hypothetical site. For example, a site may have areas where land-use decisions have been made: some restricted (e.g., a designated disposal site) and other areas assumed to be unrestricted (e.g., a commitment to a release land for an ecological reserve). Other contaminated areas may be excluded due to a lack of acceptable technology as in the case of contaminated wetlands. For areas where land-use decisions have not been made, assumptions regarding remedial strategies were made to conduct the analyses.



1 Examples are underground test areas and large surface water areas.
2 In Record of Decision, signed agreements with site owner or where only one remedy is technically feasible.

Figure 5.2. Site Land-Use Illustration

In the Base Case cost estimate, a restricted future use assumption for a specific site reflects a current or anticipated agreement with regulators or stakeholders, or an interim determination based on what remediation goal is achievable using existing technologies. The Administration has proposed legislative changes to the Superfund law to allow such considerations to be used to a greater extent in selecting remedies. In some cases, the cost estimates reflect projections of actions that assume these changes to the law are enacted because unrestricted land use was not achievable using existing technologies. Depending on possible legislative changes, and the outcome of land-use decision processes, final land use at any site or area within a site might be more or less restricted than assumed in the Base Case.

Making Sound Land-Use Assumptions: The Department's Future Use Project

To ensure that the Department's remediation efforts reflect the surrounding communities' interests in future land use, the Department initiated the "Future Use" project in winter 1994. This planning initiative encourages stakeholders to help define preferred future uses for Department of Energy installations.

At certain sites, Environmental Management Site-Specific Advisory Boards, comprised of a wide range of stakeholders, are taking the lead in formulating recommendations on future uses. At other sites, the Department is using focus groups, public meetings, individual meetings, and other mechanisms to formulate preferred options. The Department intends to use these stakeholder-preferred future use recommendations as a guide in working with its regulators—the U.S. Environmental Protection Agency and States—to identify appropriate remedial methods.

In conjunction with these efforts, the Department is assessing its land, facilities, and other assets to identify those assets that could be released for use by other federal agencies, State, Tribal, and local governments, and the private or non-profit sectors. This effort has already met with success in Florida as evidenced by the recent sale of the Pinellas Plant to the County of Pinellas for continued private industrial use. In Washington State, the Department also plans to release large portions of the Hanford Site that are no longer needed to carry out its current or future missions. In some cases, the Department will enter into leasing arrangements to maintain the option to use land or facilities for future mission needs. The Department is committed to engaging all affected and interested stakeholders in thinking strategically about which facilities, land, and other assets are suited for disposition and viable for reuse.

5.1.2 Land-Use Extremes

As depicted in Figure 5.1, the concepts of the "Iron Fence" and "Green Field" illustrate the two extremes of potential land use. The Iron Fence, or most-restricted case, is characterized by containing rather than treating or removing contamination. In contrast, the Green Field, or least restricted case, would be characterized by the removal or destruction of contaminants. These cases were examined to better understand the full range of costs associated with various land uses. Table 5.1 compares key assumptions for the range of land-use scenarios described below.

Iron Fence Case

Implementing a complex-wide Iron Fence case would actually be unrealistic because, at some sites, it is more costly to keep contamination from spreading than to remove it altogether. In addition, containment strategies would not meet contractual or legal requirements at all installations. Finally, the Iron Fence case ignores many of the legal, moral, and political commitments associated with the existing Department of Energy cleanup program.

For purposes of this comparative analysis, however, all contaminated sites were assumed to be addressed by simply containing contamination in the Iron Fence case. This means that contaminated soil and buried waste sites would be capped, contaminated ground water would be controlled from spreading by hydraulic controls and barriers, and facilities would be entombed in place.

Table 5.1. Basic Assumptions for Land-Use Cases

	Iron Fence	Modified Containment	Base Case	Modified Removal	Maximum Feasible Green Fields
Facilities	All facilities stabilized; collapsed and entombed	All facilities stabilized; at variable sites, all facilities are collapsed and entombed	All facilities stabilized; some facilities collapsed and entombed; some removed	All facilities stabilized; at variable sites, all facilities are removed	All facilities stabilized and removed
Buried Waste	All buried waste left in place	All buried waste left in place at variable sites	Some buried waste removed; some left in place	All buried waste removed at variable sites	All buried waste removed
Ground Water	All ground water contained if technologically feasible	All ground water contained at variable sites if technologically feasible	Some ground water remediated; some contained	All ground water remediated at variable sites if technologically feasible	All ground water remediated if technologically feasible
Contaminated Soils	Soils capped, stabilized in place, or untouched	All contaminated soil capped or stabilized at variable sites	Some contaminated soil capped; some removed	All contaminated soil removed at variable sites if technologically feasible	All contaminated soil removed if technologically feasible

* Some sites were excluded from the analysis because no feasible technological remediation strategy exists (e.g., nuclear weapons underground test areas) (see table 3.1 for list of exclusions).

The estimated cost of the Iron Fence case is approximately $175 billion. This estimate assumes productivity improvements similar to those of the mid-range Base Case. It is important to note that approximately $25 billion of this estimate is for containment activities while the remaining $150 billion is associated with managing existing waste and stabilizing special nuclear material and facilities (e.g., vitrification and disposal of high-level waste and dispositioning plutonium scraps and residues).

Maximum Feasible Green Fields Case

In contrast to the Iron Fence case, which may be unrealistic from a legal or policy perspective but technically achievable, a complex-wide Green Fields case is both technically infeasible as well as programmatically unrealistic. Most importantly, as pointed out in the discussion of the Base Case assumptions, certain sites cannot be remediated to risk levels associated with unrestricted land use with existing remedial technologies. Moreover, a complex-wide Green Fields case would preclude establishing any waste disposal areas, which are by necessity restricted areas. Hence, a complex-wide Green Fields case was not analyzed.

For the purposes of this analysis, a "Maximum Feasible Green Fields" case was developed that assumed containment and restricted land use for all release sites

where current technologies are unavailable or those sites being used for active disposal. For all other release sites, aggressive removal strategies were assumed, including exhumation of contaminated soil and demolition of buildings with all contaminated media removed from the site. As discussed, containment strategies generally involve containing waste in place with caps and other barriers. These strategies will not support unrestricted land use because over long periods of time, normal activities associated with residential, agricultural, and other unrestricted uses could result in breaching of caps or unearthing of unstabilized materials.

The Maximum Feasible Green Fields case was estimated to cost approximately $500 billion. As with the Iron Fence case, the estimates assume productivity improvements similar to those of the mid-range Base Case. The significant difference in cost between the Iron Fence and the Maximum Feasible Green Fields cases—approximately $325 billion—stems from the use of containment strategies versus removal strategies.

Removal and containment technologies differ in the types and amounts of waste they generate—sometimes referred to as secondary waste. Most containment technologies produce little or no secondary waste. In contrast, most materials removed or excavated using removal technologies (e.g., soil washing) are considered waste and require subsequent transportation, storage, treatment, and disposal. Thus, waste management costs increase whenever a removal technology replaces a containment technology. Removal and containment technologies also differ in the amount of required post-remediation surveillance and maintenance. Because containment strategies result in more waste being left in place, some type of institutional controls to monitor the waste and replace or repair containment structures is required. Thus, over the long term, additional surveillance and maintenance costs are incurred indefinitely in conjunction with containment strategies.

5.1.3 More Realistic Land-Use Alternatives

To estimate the costs for more realistic land-use scenarios, the assumptions used for the extreme scenarios were modified. Two additional scenarios, referred to as the "Modified Containment Case" and the "Modified Removal Case," were developed. To develop these scenarios, certain assumptions from the bounding cases were combined with assumptions from the Base Case. This involved categorizing sites into those where land-use decisions are relatively firm versus those where future land use is less clear. (See Section 5.1.1 for a discussion of factors influencing land-use assumptions.)

Table 5.2 divides sites into those where land-use assumptions were varied and those that were held constant (i.e., not changed from Base Case assumptions). Site land-use assumptions and their corresponding activities were held constant for sites listed in the first column for both the Modified Containment case and Modified Removal case. Most of the unchanged assumptions at these sites originate from legally binding contracts, records of decision, designation for permanent disposal sites, or other departmental commitments. For the sites listed in the second column of Table 5.2, land-use assumptions were varied from case to case. These sites are typically large sites with differing levels of contamination throughout the site, where final land-use options have not been determined.

Table 5.2. Sites Varied in Land-Use Analysis

State	Areas with Unchanged Base Case Land Use Assumptions	Areas Where Land Use Assumptions Were Varied From The Base Case
California	Energy Technology Engineering Center General Atomics Center General Electric Vallecitos Geothermal Test Facility Lab for Energy Related Health Research Oxnard Stanford Linear Accelerator Center	Lawrence Berkeley Laboratory Lawrence Livermore National Laboratory Stanford Linear Accelerator Sandia National Laboratory-Livermore
Colorado	Grand Junction Vicinity Properties Rocky Flats Plant Protected Area, D&D, Solar Pond	Rocky Flats Plant Remainder of Site
Florida	Pinellas Plant	
Idaho	Argonne National Laboratory-West Idaho National Engineering Laboratory WAGs 1, 2, 4-7 Idaho Chemical Processing Plant	Idaho National Engineering Laboratory WAG 10
Illinois	Argonne National Laboratory -East Site A/Plot M, Palos Forest Reserve Fermi National Accelerator Laboratory	
Iowa	Ames National Laboratory	
Kentucky	Maxey Flats	Paducah Gaseous Diffusion Plant
Missouri	Kansas City Plant Weldon Spring Site	
Nebraska	Hallam Nuclear Power	
Nevada	Nevada Test Site Underground Test Areas	Nevada Test Site - Remainder of Site
New Jersey	Princeton Plasma Physics Laboratory	
New Mexico	Inhalation Toxicology Research Institute Waste Isolation Pilot Plant South Valley Site	Los Alamos National Laboratory Sandia National Laboratory-Albuquerque
New York	Separation Process Research Unit West Valley Demonstration Plant	Brookhaven National Laboratory
Ohio	Battelle-Columbus Fernald Environmental Management Project, Surface and Facilities Mound Plant Piqua Nuclear Power Facility RMI Titanium, Inc.	Portsmouth Gaseous Diffusion Plant Fernald Environmental Management Project Groundwater
South Carolina	Savannah River Site WAGs 1, 3, 9 (Areas A&M, Reactors, D&D)	Savannah River Site WAGs 2, 4-7
Tennessee	Oak Ridge Associated Universities Oak Ridge Offsite	K-25 Site Oak Ridge National Laboratory Y-12 Plant
Texas		Pantex Plant
Utah	Monticello Mill Site & Vicinity Properties	
Washington	Hanford Site 1100, 200 Areas	Hanford Site 100, 300 Areas
Multiple	FUSRAP Sites Nevada, Sandia Nat. Lab, Grand Junction Offsites UMTRA Sites Surface	UMTRA Sites Groundwater

For the sites with relatively firm land-use plans, costs developed for the Base Case were substituted for the costs of remediation assumed in the extreme cases, whether it was removal or containment. For the balance of the sites, where future land use is yet to be resolved, the results from the Iron Fence case or the Maximum Feasible Green Fields case were used. Therefore, the Modified Contaminated case results in a less restricted land-use scenario than the Iron Fence case, and the Modified Removal case results in a more restricted case than the Maximum Feasible Green Fields case.

Modified Containment Case

The Modified Containment case and the Base Case land-use activities differ by the amount of contamination contained versus contamination removed at sites where land-use assumptions were varied (Table 5.2, column 2 sites). All Base Case removal activities at these sites were replaced by containment activities. In other words, as shown in Table 5.1, buried waste was left in place, contaminated soil was capped or stabilized, facilities were stabilized, collapsed and entombed in place, and ground water was contained if technologically feasible.

The Modified Containment case cost estimate is approximately $225 billion. This estimate is approximately $5 billion less than the Base Case estimate of $230 billion. This difference results from eliminating removal activities that were assumed for the Base Case. The Modified Containment case estimate is $50 billion higher than the Iron Fence. This difference is from assumed removal activity at the sites where land use was held the same as (Table 5.2, column 1 sites) that of the Base Case.

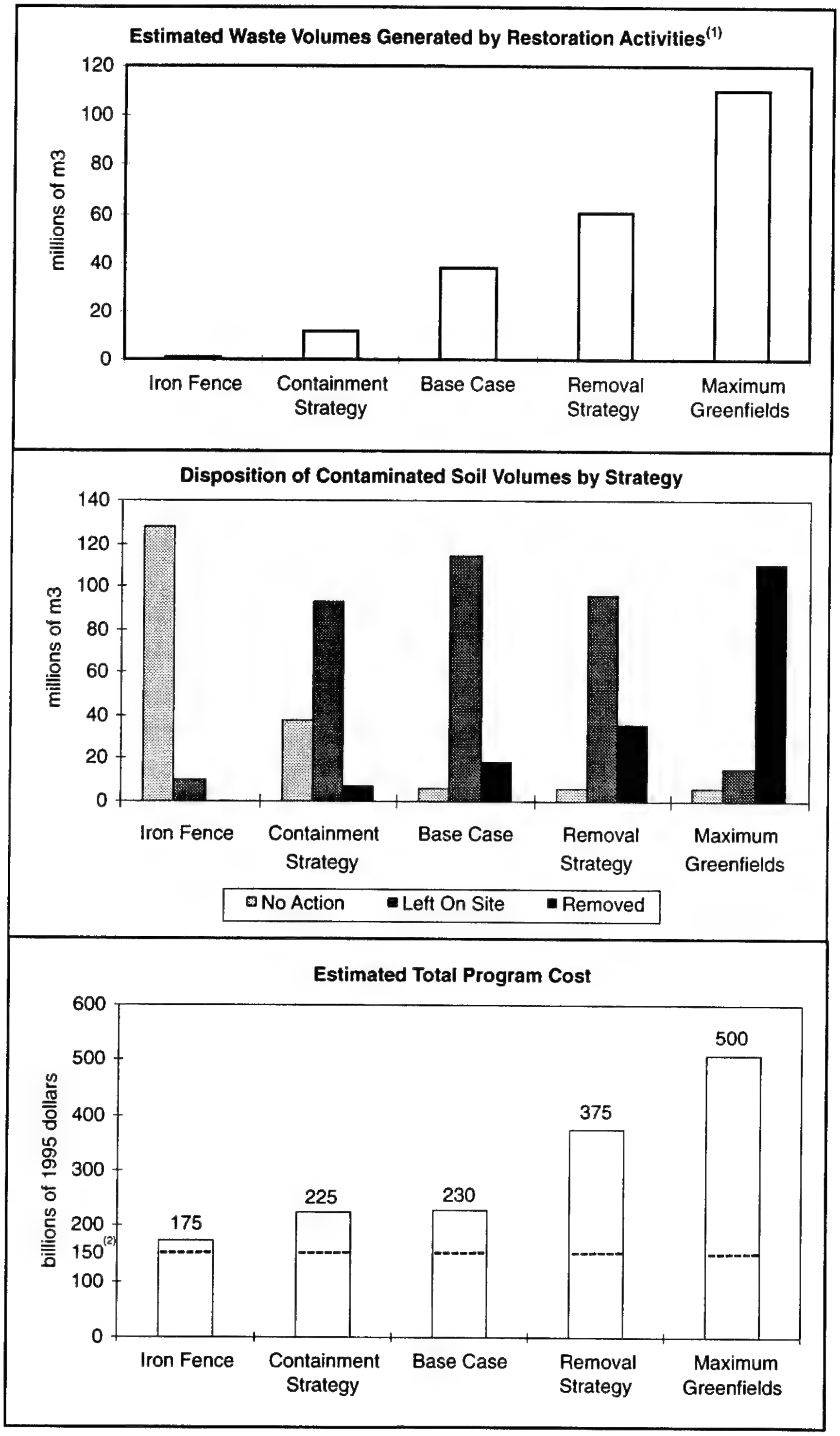
Modified Removal Case

Alternatively, the Modified Removal case and the Base Case scenarios differ by the amount of contamination removed versus contained at sites where assumptions were changed relative to the Base Case. All Base Case containment activities were assumed to be removal activities in this case. As a result, all buried waste, contaminated soils, and facilities were removed, and ground water was remediated if feasible.

The estimated cost of the Modified Removal case is $375 billion. This estimate is $145 billion higher than the Base Case estimate as a result of increased removal activity. The estimate remains $125 billion below the Maximum Feasible Green Fields case because of the containment activities at the sites where land use was unchanged from that of the Base Case.

Comparison of Cost Estimates

Figure 5.3 illustrates how total program cost is a function of the difference in scope and remedial strategies required to meet the different land-use goals. The first box of Figure 5.3 shows total amounts of waste produced by restoration activities under each of the five cases. Estimated are final volumes of remediated media (e.g., treated soils, secondary waste, treated ground water), which increase steadily as more aggressive removal strategies are implemented. The second box represents changes in initial volumes of contaminated soil assumed under the no action; treated but left onsite; or removed from the site remedial strategies. The results



(1) Includes mill tailings, sanitary waste, low-level waste, low-level mixed waste, transuranic waste, and hazardous waste

(2) Approximately $150 Billion in costs are from managing existing wastes and surplus contaminated facilities

Figure 5.3. Results of Land-Use Analysis

show that Base Case land-use assumptions result in large volumes of contaminated soil being contained rather than removed.

Referring again to our hypothetical site, Figure 5.4 depicts the five land-use cases that were analyzed. One can follow the decrease in restricted land-use areas from the Iron Fence to Green Fields cases and the associated increase in costs.

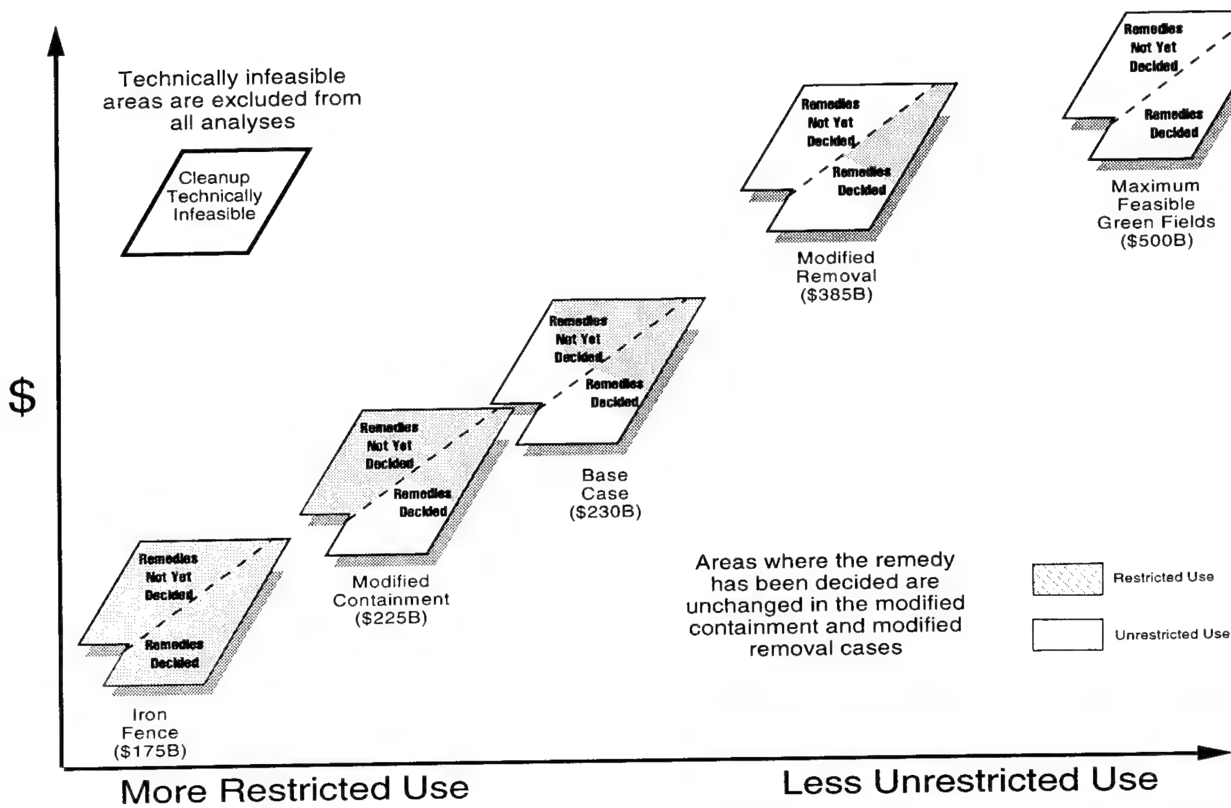


Figure 5.4. Land-Use Case Relationships

5.1.4 Potential Effects of Residual Contamination Standards

Although the general goal of environmental restoration is cleanup, no universal answer exists to the question "how clean is clean?" Cleanup under the Comprehensive Environmental Response, Compensation and Liability Act is considered complete if existing Federal and State cleanup standards are met. Remediation decisions are being made now, consistent with the Comprehensive Environmental Response, Compensation, and Liability Act and the National Contingency Plan, which identifies the regulatory parameters for developing, evaluating, and selecting a cleanup strategy or remedy. Such standards exist for drinking water supplies (protection of human health) and surface waters (protection of ecosystems). Few such standards exist for soils, even for hazardous chemicals, and standards designed specifically for cleanup of most radionuclides in soil do not currently exist.

The only standards designed for the cleanup of radionuclides are those for land and buildings contaminated by uranium mill tailings at inactive uranium-processing sites.

Under the Comprehensive Environmental Response, Compensation, and Liability Act, risk assessments are conducted to determine the relationship between contaminant concentrations at the affected site and the likelihood of adverse effects to human health and the environment, also referred to as risk estimates. Cleanup levels are established by calculating the expected lifetime cancer risk from the risk estimates. Cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act is considered complete if residual contamination will result in a calculated human health risk of 1 statistical cancer death in a population of 1 million individuals (i.e., 10^{-6} risk level) for radionuclides. The 10^{-6} calculated risk level represents the "point of departure" with waivers from this criterion considered for cleanup technology limitations and other limiting factors.

Ongoing Efforts

In an effort to remedy the lack of consistent radiation cleanup standards, the U.S. Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) are developing the Radiation Site Cleanup Regulation (40 CFR 196) and Radiological Criteria for Decommissioning (10 CFR 20), respectively. These regulations will apply to Department of Energy and Department of Defense sites, and sites licensed by the NRC and its "Agreement States." An EPA/NRC Memorandum of Understanding (57 FR 54127) discusses how the two agencies' parallel approach will yield regulations which are consistent, fully protective of public health and the environment, and issued in a timely manner. The proposed cleanup standard is a dose limit of 15 mrem/year above natural background levels. This corresponds to a 10^{-4} lifetime excess cancer risk which is consistent with other radiation protection programs and standards, and is at the upper end of the Comprehensive Environmental Resource, Compensation, and Liability Act risk range. Cleanup for unrestricted residential use is the goal; however, land use restrictions will be allowed as long as a maximum proposed dose limit of 75 mrem/year or 100 mrem/year (NRC) is not exceeded if active control measures (e.g., engineered barriers) fail.

Applying the Comprehensive Environmental Response, Compensation, and Liability Act risk assessment approach to establish cleanup standards for radionuclides creates special difficulties. As cleanup levels become more stringent, the ability to distinguish between naturally occurring radioactive material and radioactive contamination becomes technically difficult and/or infeasible. Under a residential land-use scenario, carcinogenic risk associated with the natural background levels of some radionuclides exceeds the 10^{-6} risk range specified in the Comprehensive Environmental Response, Compensation, and Liability Act. For example, the risk goal for radium-226 in soil is 0.1 picocuries per gram or less, but natural background levels in the United States vary from 0.23 to 4.2 picocuries per gram, and background measured at three Department of Energy installations ranged from 0.59-2.5 picocuries per gram (Fernald) and 0.31-1.4 picocuries per gram (Weldon Spring) to 0.55-1.4 picocuries per gram (Oak Ridge).

As is the case for land use, the Base Case incorporates each installation's assumptions regarding current and likely future decisions regarding cleanup levels. Because specific cleanup levels generally are determined case by case, it is difficult to anticipate the ultimate residual contamination standards that will be selected for each site. Current information and the tools available to prepare the cost estimates for this report (i.e., the modeling capability) are insufficient to determine the magnitude of importance of these decisions on total program cost. However, several lines of evidence suggest that the cost implications of cleanup level decisions are closely related to land-use decisions.

Figure 5.5 illustrates how land use and residual contamination standards applied to the same soil contamination release site might affect ultimate remediation. Generally, changes in cleanup standards are considered less likely to cause a shift in remediation strategy (i.e., from containment to active remediation) than are changes in assumed land use. However, changes in standards will affect the amount of work required for a given strategy, as seen in Figure 5.5. For a restricted land use, using a capping approach under different residual standards, the remedial approach might reflect a larger cap under a cleanup standard based on the 10^{-6} risk level than the 10^{-4} level. In both instances, the containment approach would result in very little secondary waste. If unrestricted land use is assumed, more contaminated soil may have to be removed under the more stringent residual contamination standard than the less stringent standard.

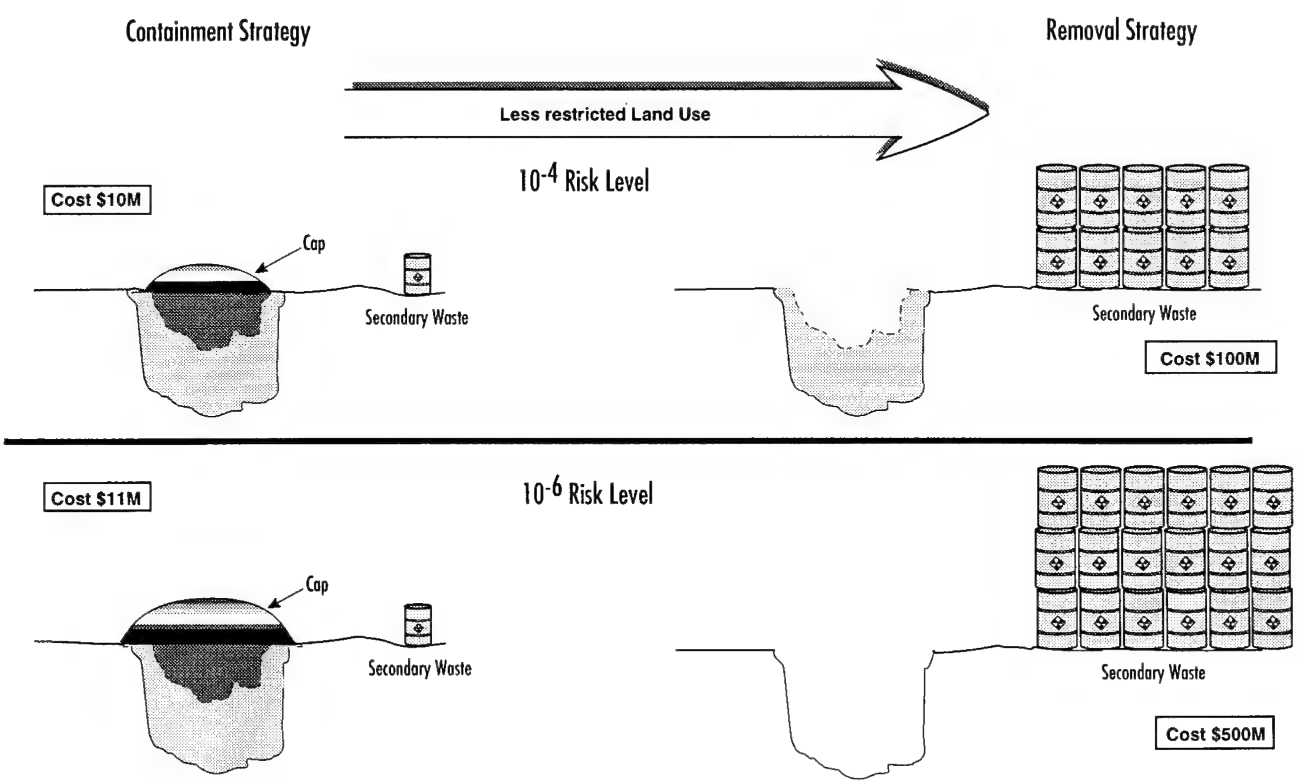


Figure 5.5. Illustration of Land Use and Residual Contamination on Environmental Restoration Costs and Volumes

The primary, yet tentative, conclusion to draw from this is that more stringent cleanup standards will equate to greater cleanup (and greater costs) if active remediation approaches are assumed. In the event of containment approaches, the effect on the work scope (and cost) is likely to be minimal. Figure 5.6 conceptually illustrates the causal interrelationship among costs, land use, and residual contamination. Two possible relationships are presented because not enough analysis has been conducted to determine the precise relationship among the variables. Because of the relative positioning of the Base Case and the land-use alternatives toward the restricted end of the land-use continuum, Figure 5.6 suggests that residual contamination standards may have a relatively small effect on total cost for the land-use cases considered in the reasonable range. However, if the program were to move toward more unrestricted land use, Figure 5.6 suggests that residual contamination standards might significantly affect total program cost.

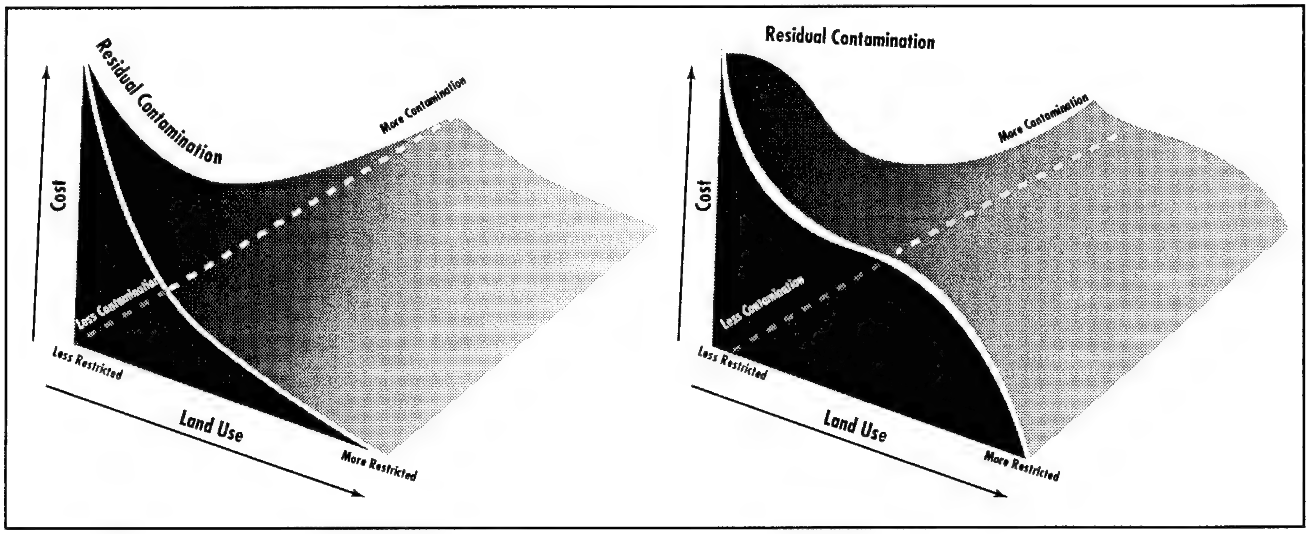


Figure 5.6. Conceptual Illustration of Potential Relationship Between Land Use, Residual Contamination, and Total Program Cost

More information must be collected and analyses conducted to determine both the precise shape of the graphs and the Base Case position on the graph for the Department of Energy complex as currently configured. The Office of Integrated Risk Management within the Environmental Management program provides a focal point to better assess the occupational and environmental risks at Department of Energy installations and assist in establishing priorities based on mitigating the most urgent risks first. Increased information on risk will help to determine the eventual scope of the Environmental Management program. This risk information also will help to determine the relative importance of residual contamination standards on total program cost. Future reports will incorporate the results of these related efforts.

Land-Use Agreement Affects Residual Contamination Goals at Fernald

Revised future land use has influenced residual contamination goals at the Fernald Site, resulting in an estimated environmental restoration cost savings of approximately $1 billion or about 15 percent of the life-cycle cleanup estimate. The original land-use scenario included potential use as a residential and agricultural area, requiring that large quantities of soil be removed and disposed of offsite. The Fernald Citizens Advisory Group evaluated alternative land-use options including industrial and recreational uses. The group recommended a land use that (1) supports protection of the underlying aquifer with active ground-water remediation to attack existing contamination and removal of prime sources of ground-water contamination limiting future additional contamination; (2) establishes a disposal cell onsite; and (3) excludes certain types of waste from being left onsite, including process residues currently stored in the silos. Consideration of a future land use with fewer potential means of exposure to the public allowed cleanup plans to include less removal of contaminated soil (i.e., greater residual contamination roughly equivalent to a calculated 10^{-5} risk level). This case illustrates the interrelationship between land use and residual contamination and the successful balancing of local stakeholder concerns with the national goal of cost-efficient cleanup.

5.2 Funding and Scheduling Analysis

The primary assumption driving schedules in the Base Case is that funding will be sufficient to fulfill previously negotiated compliance agreements and will remain constant thereafter. With the exception of the Hanford Tri-Party Agreement, most compliance agreements extend no farther than the year 2000. For the Base Case, the schedule of activities at a site is determined by the level of funding assumed available. Because it is not possible to anticipate specific funding levels set by congressional appropriations, annual funding levels are likely to differ from those assumed in the Base Case—perhaps higher, perhaps lower. To provide an indication of the efficiencies that could be gained or lost if funding is higher or lower than assumed, the Department examined how total program cost might be affected by examining alternative ways to schedule and pace the Environmental Management program activities. Projected savings discussed below are in constant 1995 dollars and include productivity assumptions.

5.2.1 Accelerating Stabilization Activities

For this case, the Department accelerated surplus facility stabilization projects to reduce surveillance and maintenance costs. Surveillance and maintenance activities are required to maintain facilities in a safe condition while they await stabilization. Typically, once surplus facilities are transferred to Environmental Management, they are not immediately stabilized because of the expense of these operations, and therefore, have to undergo pre-stabilization surveillance and maintenance for a number of years. For purposes of this analysis, the assumed duration of pre-stabilization surveillance and maintenance was reduced from 10 years (the Base Case assumption) to 1 year. In other words, stabilization activities were assumed to begin almost immediately after transfer.

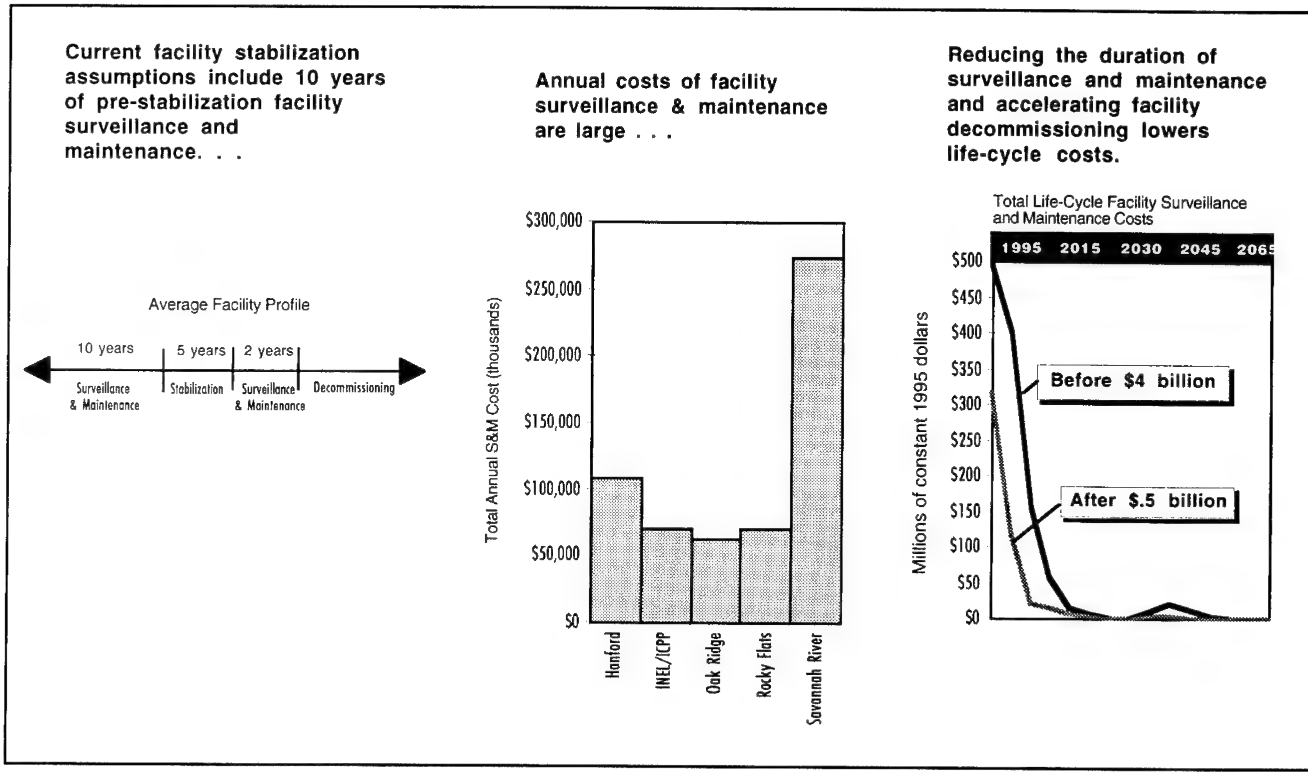


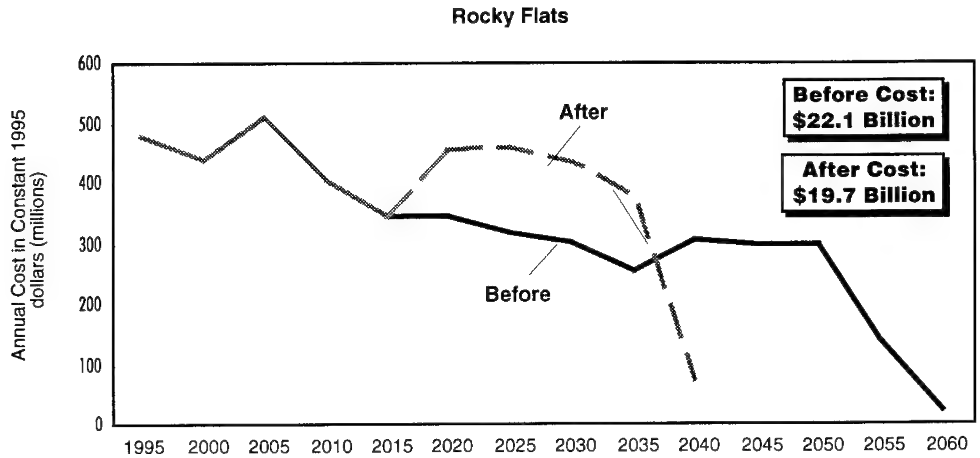
Figure 5.7. Potential Savings from Accelerating Facility Transition to Decommissioning

Annual cost during the early years of the program increased because stabilization costs are generally higher than surveillance and maintenance costs. To accommodate the increased costs, the Department relaxed the assumption that funding would remain constant after activities in existing compliance agreements were met. This allowed activities to be scheduled at a greater pace early in the life of the program.

For this case, life-cycle surveillance and maintenance costs were reduced to approximately $500 million, approximately 87 percent lower than the $4 billion estimated for the Base Case.

5.2.2 Early Site Closures

The Department also developed and analyzed three case studies to indicate potential cost savings derived from accelerating the scheduled completion for all activities at an installation. Closing a site more quickly would reduce overall costs by reducing the time landlord and other support activities would be required. The costs for these types of activities, which are generally considered fixed (they do not vary with the amount of work being done), would therefore be reduced. With an accelerated schedule of activities, annual site costs would increase in the early years of the total cost estimate. As with the example in Section 5.2.1, the available funding limit was relaxed for purposes of this analysis. Case studies were conducted for the Rocky Flats Plant and the K-25 Site at Oak Ridge.



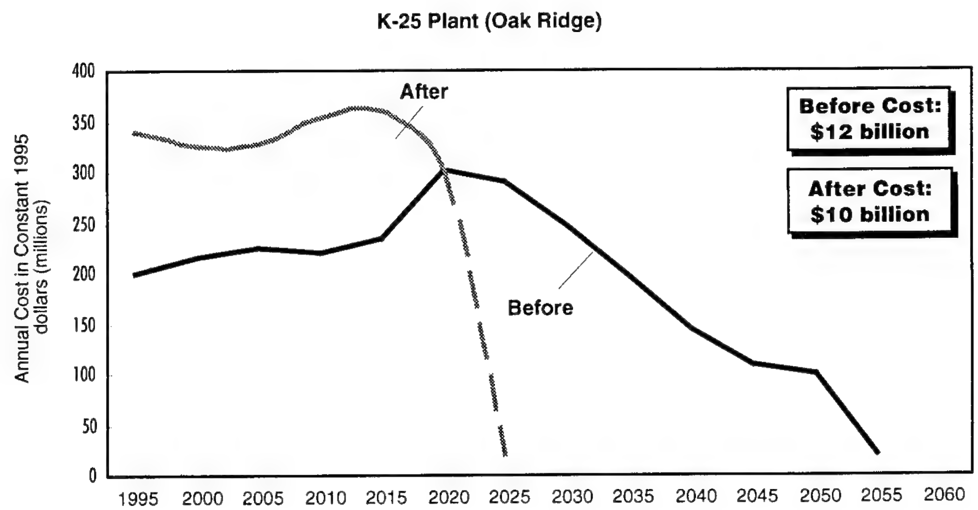


Figure 5.8. Potential Savings from Accelerating Site Closure are Large: Two Case Studies

Figure 5.8 presents cost savings for two of the three case studies in which environmental management activities are accelerated. For the Rocky Flats Plant, accelerating site closure by 20 years led to an estimated savings of $2.4 billion. At the K-25 Site, accelerating closure by 30 years led to an estimated savings of approximately $2 billion. As expected, the majority of these savings were in fixed support costs at these sites.

5.2.3 Minimal Action

In the first two examples, which assumed no annual funding limits, a Minimal Action case was analyzed under the assumption that available annual funding would be significantly reduced beyond the year 2000. Assuming this, the Department sought to analyze the minimum amount of activity required for this program, as well as costs of this type of strategy both annually and cumulatively.

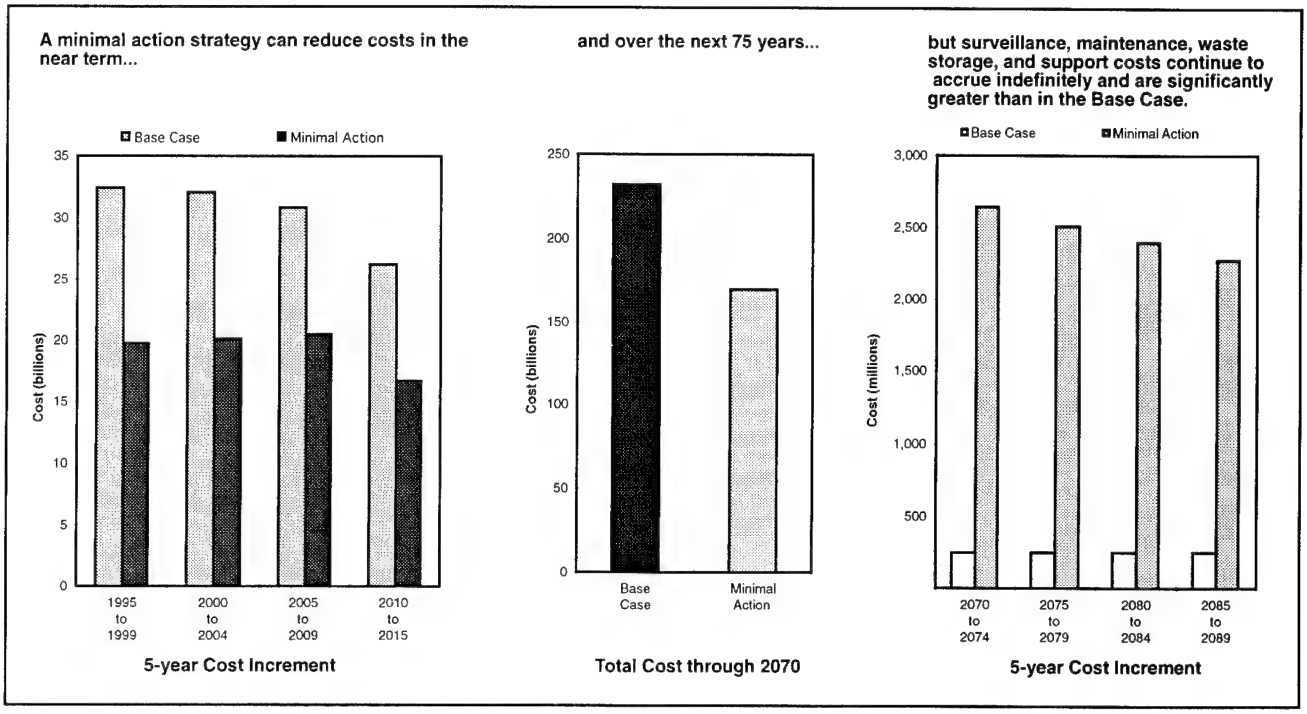


Figure 5.9. Minimal Action Reduces Near-Term Costs But Increases Future Liabilities

Those activities assumed to be required in the program for this analysis include treatment and disposal of all high-level waste and spent nuclear fuel; stabilization and surveillance and maintenance of surplus facilities; and safe *storage* of all low-level, low-level mixed, and transuranic wastes.

Those activities excluded from the program for this analysis include environmental restoration; decontamination and dismantlement; and all *treatment* and *disposal* activities associated with low-level, low-level mixed, and transuranic wastes.

The Minimal Action scenario assumes that all high-level waste and spent nuclear fuel is disposed as assumed in the Base Case and existing volumes of low-level, low-level mixed, and transuranic wastes remain in pretreatment storage indefinitely; and that remediation activities planned in the Base Case are not conducted.

For this case, the total cost estimate of approximately $170 billion is about 27 percent lower than the Base Case through the year 2070, as shown in Figure 5.9. Total estimated cost for the first 20 years of this case (approximately $80 billion) is about 40 percent lower than the corresponding estimate for the Base Case ($122 billion). However, after 2070, the estimated annual program cost is approximately $50-75 million for the Base Case for long-term surveillance and maintenance of disposal sites and restricted access sites. Annual costs in the minimal action case after 2070 are approximately $500 million for waste storage and surveillance and maintenance.

The end date for the minimal action case was set at 2070 for purposes of comparison to the Base Case. Obviously, as the period of analysis is extended, the minimal action case costs will grow in relation to Base Case costs and eventually exceed

them. Additionally, this analysis does not attempt to assess the potential increases in risk associated with ceasing to perform remediation and decontamination activities. However, risk to workers and the public may significantly increase under this approach.

These analyses illustrate that total program cost may be affected by the overall pacing of Environmental Management activities. Annual costs for surveillance and maintenance for some facilities will be high until they are safely stabilized. Landlord and other support costs will be incurred until all Environmental Management activities are finished at an installation. Thus, a dynamic relationship appears to exist between annual and total program costs. Within some limits, increasing the pace of activities, while resulting in increased annual costs, appears to decrease total cost.

5.3 Technology Development

The Environmental Management technology development program addresses a spectrum of innovative technologies dealing with such areas as site characterization, capping and barrier containment, and the removal of radionuclides. Newly introduced characterization and remediation technologies have yielded over $115 million in cost savings to date. Emphasis is being placed on development of less costly systems and on "enabling technologies" that address cases where no feasible or acceptable technical solution currently exists to remedy a site. Technologies that reduce worker and public risk also are receiving major attention.

Achieving Improvements in Technology

Examples of the initial application of innovative technologies involve characterization, treatment, and in situ remediation. At the Pantex Plant, innovative methods for site characterization at 1 operable unit resulted in cost reductions of about 66 percent or about $3 million. Use of innovative ground-water treatment technologies at the Lawrence Livermore National Laboratory in California resulted in a calculated cost savings of $19 million and site remediation in months rather than decades. Using a more flexible waste stabilization methodology at Fernald has resulted in cost savings of over $30 million.

Risk Reduction Approaches

Robotics retrieval and characterization devices will make possible the removal of otherwise nonretrievable high-level waste from tanks and much safer investigation of tank contents. Other robotics systems will permit very precise removal of buried, solid waste and remote controlled dismantlement of equipment in gas diffusion plants should the worker risk of conventional technologies be unacceptable. In situ bioremediation technologies and in-well treatment systems will destroy hazardous components underground and collect a minimum volume of radioactive components for removal and safe disposal at significant cost savings and reduced risk compared to conventional excavation and pump/treat strategies. Improved vitrification technology will produce a more durable waste form for disposal and could provide a more controllable, safer treatment process as an alternative to incineration.

A key assumption for the Base Case is that current technologies will be used as the basis for life-cycle cost estimates for the Environmental Management program. Given that the Base Case activities are projected to continue until 2070 and beyond, it is expected that a variety of new, more efficient, and effective technologies will be introduced in future years. The productivity assumptions incorporated into the Base Case account for approximately $121 billion in cost savings over the life of the Environmental Management program. A portion of these savings is assumed to come from new technologies. This analysis provides examples of the potential savings that may result through the implementation of a number of innovative technologies. The following analysis involved a limited set of technologies under development and addressed only some of the Environmental Management program's identified remediation and treatment problems. For this reason, the potential savings identified should be viewed as a fraction of the total potential for the technology development program. Future reports will incorporate a broader analysis.

5.3.1 Impacts of New Technology

New technologies may enable a site to be remediated without removal of contaminated material (e.g., in-place destruction or treatment) or may reduce the amount of waste produced during removals (and hence reduce secondary waste management costs). Further, improved technologies will enable problems which currently have no feasible solution to be addressed, such as the removal of solids from high-level waste tanks. Such technologies may increase the degree of remediation that is possible for a given level of funding and reduce risks to workers and the public. These types of benefits are not included in this analysis.

The Base Case emphasizes containment and institutional controls for many soil projects and most ground-water projects, thus limiting the applicability of improved waste removal and in-situ and ex-situ treatment technologies that were the focus of this analysis. Significant work is being done on improved barrier and containment technologies, but potential savings in these areas has not yet been analyzed. To understand the impact of new removal technologies under a more active remediation strategy, costs savings were also estimated based on the more active remediation land use case assumptions (see Section 5.1).

Case Study: Advanced Ground-Water Technologies at Savannah River

A case study was made of the ground-water contamination problem at the Savannah River Site. If conventional pump and treat remediation strategies were replaced with microbial filters or reactive barriers inserted in the aquifer to intercept the contaminant plume, savings of $130 million, or 33 percent, of the current estimated costs for ground-water remediation could be saved. These technologies are anticipated to be available sometime between the years 2000 and 2015. Longer range improvements to reactive barriers would employ engineered sequestrants to trap specific radionuclides in their molecular structure and achieve even more cost savings.

Table 5.3. Technology Systems Used to Estimate Potential Cost Savings

Technology	Analysis
Soil remediation	Electrokinetics–collects radionuclides and heavy metals around in-ground electrodes; contaminants are subsequently removed for disposal. Innovative soil washing–an ex-situ treatment to remove normally immobile metal ions, including radioactive contaminants like cesium. In situ vitrification–creates a glass-like monolith that immobilizes contaminants in the solid matrix in the ground.
Groundwater	Recirculating wells–pumps groundwater through in-well modules designed to selectively remove contaminants. Microbial filters–selected microbes are placed across the flow path of contaminated groundwater so that eventual contaminant-microbe contact will permit microbial degradation of the waste. In situ bioremediation–either stimulation of indigenous microbes or insertion of foreign microbes in the contaminated region to promote contaminant elimination by microbial metabolism. Dynamic underground stripping–injection of steam into the contaminant plume to volatilize the waste species and sweep them to centrally located extraction wells. Biosorption of uranium–removal and concentration of uranium-238 from wastewater using non-living biomass that is immobilized in an inert material.
Facilities	Automated facility dismantlement–robotic systems disconnect and remove contaminated equipment. Gas phase decontamination–surface decontamination of bulk metal by long-term (3-month) exposure to ClF_3, at ambient temperature.
Buried waste	Selective retrieval–telerobotic systems to perform real-time monitoring for contaminants, three dimensional imaging of sites underground, dig-face characterization, and remote retrieval of contaminated waste. Automated waste handling–telerobotic systems to perfom cryogenic cutting without creating secondary waste streams, excavate and convey waste, and assay waste samples.
Mixed low-level Waste Treatment	Plasma hearth system–high-temperature vitrification that produces a leach-resistant glass without the need for extensive pretreatment of the waste to be vitrified and significantly reduces disposed volumes.
Characterization	Expedited site characterization–a multi-disciplinary team of experts use a variety of new sensor/analytical technologies in real time in the field to produce a more accurate, complete site characterization.
High-level waste	Efficient separations–chemical pretreatment processes that segregate high-level waste into component waste streams to reduce the total volume of high-level waste to be handled.

5.3.2 Analytical Approach

This sensitivity analysis was conducted in two parts: to yield a low-end estimate of potential cost savings based on the Base Case strategy and a high-end estimate, based on the aggressive Remediation Case strategy. Over 100 potential technology systems scheduled to be ready for implementation by the year 2000 were screened based on their potential applicability to high-cost remediation projects in the Unrestricted Land Use case. Of these, 15 were selected and used to evaluate potential cost savings when applied to specific projects (see Table 5.3).

These same 15 technology/systems were also evaluated for applicability to the Base Case.

There are significant potential applications for these improved technologies. Cost savings were estimated for specific projects and applied to the balance of projects in the program with similar contamination problems. Savings projections were based on field data regarding waste volumes and projected unit costs of current technologies versus innovative technologies.

The technology savings calculated were then reduced by applying several factors to compensate for the limited information available to validate the applicability of new technologies to specific projects. Another factor was applied to account for uncertainties about the acceptance rate (by States, regulators, and private corporations) of implementing new technologies. Factors for uncertainty in project applicability and acceptance rate were combined with factors for uncertainty in technology cost to calculate the net savings.

5.3.3 Savings Projections

The potential cost savings from the implementation of these specific new technologies range from 20 percent to 50 percent of the currently estimated costs for selected projects. The estimated savings are based on program investment and technologies expected to be implemented by the year 2010. Further reductions can be expected from technologies developed after 2010. When applied to the Base Case, the minimum potential savings projected as a result of this analysis is estimated to be $9 billion dollars (about 10 percent of the projected remediation costs). Savings for the Modified Removal Case were estimated at $40 billion dollars. Minimum savings of $80 billion dollars are estimated for the Maximum Green Fields Case. Results are illustrated in Figure 5.10.

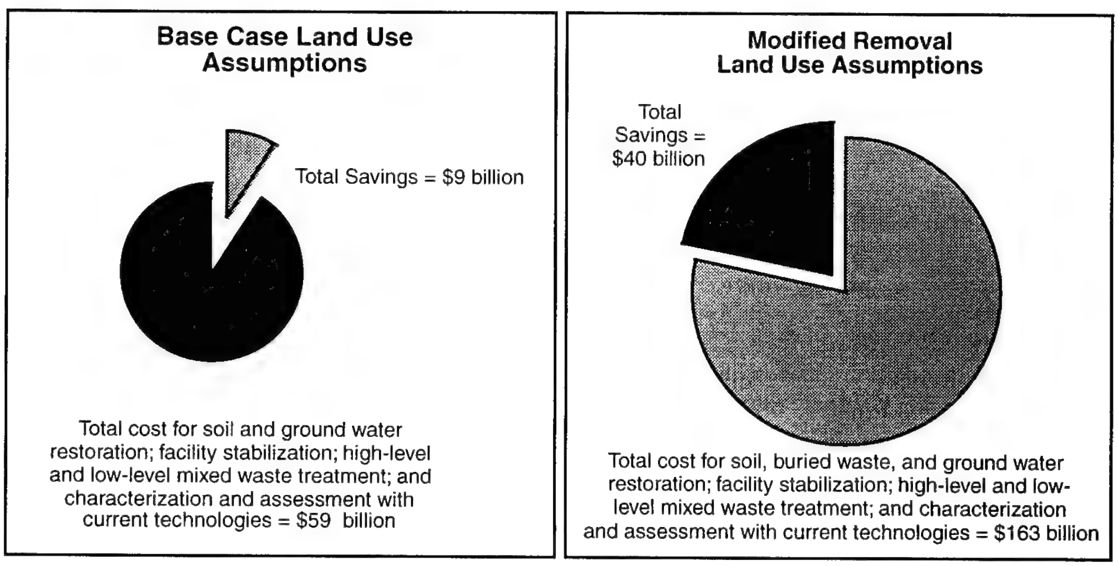


Figure 5.10. Technologies Available for Implementation by 2000 May Reduce Total Program Cost

A major benefit of enabling and lower cost technology/systems now under development may be the ability to move away from containment strategies now assumed in the Base Case in the direction of more strategies involving contaminant removal, while remaining within whatever funding level the Nation decides is appropriate for cleanup of the complex.

5.4 Waste Management Configuration Perspective on the Base Case

The Department of Energy currently is examining alternative configurations (centralized, regionalized, and decentralized) for siting treatment, storage, and disposal facilities for each waste type and spent nuclear fuel. Different alternatives offer potential positive and negative attributes. For example, a centralized alternative is usually the most cost effective. However, this approach requires large amounts of waste to be transported from various sites to a central location. This results in a higher risk to the public and workers due to increased handling as well as the transportation of the waste. Conversely, a decentralized approach would not require as much transport of waste but is usually the most expensive option. For the Baseline Report, configurations were selected for each waste type that represent current strategic approaches. Table 5.4 identifies the types of configurations used for each activity and waste type in the Base Case. The configurations used for each waste type differ as far as approach. For example, in the high-level waste program, the Department is planning to treat liquid high-level waste at the four sites where it is stored. The current plan for high-level waste is disposal in a geologic

Table 5.4. Base Case Waste Management Configuration

Waste Type	Centralized	Regionalized	Decentralized
High-Level Waste			
Treatment			X
Storage			X
Disposal	X		
Transuranic Waste			
Treatment		X	
Storage		X	
Disposal	X		
Low-Level Waste			
Treatment			X
Storage			X
Disposal		X	
Low-Level Mixed Waste			
Treatment			X
Storage			X
Disposal		X	
Hazardous Waste			X
Sanitary Waste			X

repository. The Base Case, therefore, reflects a configuration combining decentralized treatment and centralized disposal. This variation in configuration approach is true in other waste types as well. Therefore, the Base Case does not represent one configuration concept but a combination of configurations reflecting different approaches to treatment, storage, and disposal for each waste type based on different management requirements for each. In general, the Base Case represents a regionalized/decentralized approach to the treatment and storage of waste, and a regionalized/centralized approach to disposal.

The Department currently has several initiatives underway to examine the potential risks and costs of alternative configurations to managing its waste types. These efforts include the Spent Nuclear Fuel Programmatic Environmental Impact Statement, the Waste Management Programmatic Environmental Impact Statement, and the Federal Facility Compliance Act process. The Department is using these efforts to build consensus on which configurations are the most acceptable.

An example of the Department's new approach to consensus building for siting new facilities is the process used to address the requirements of the Federal Facility Compliance Act. The Act requires the Secretary of Energy to submit, for each site storing or generating mixed waste, plans for the development of treatment capacity and technologies for treating mixed waste. These Site Treatment Plans identify how the Department will provide the necessary mixed waste treatment capacity, including schedules for bringing new treatment systems into operation. At the request of State representatives, each site developed a Draft Site Treatment Plan with the emphasis on treating its low-level mixed waste onsite to the greatest extent possible. Because of the very limited amounts of some of the waste streams, especially at the smaller sites, this approach resulted in an inefficient configuration from a complex-wide perspective. The Department, in coordination with States and the U.S. Environmental Protection Agency, evaluated alternative siting options. This included examining a more centralized configuration. Analysis showed that only marginal cost savings (less than $600 million out of roughly $3 billion) could be achieved through greater centralization; however, it resulted in a substantial increase in the volume of waste shipped, particularly from one State to another. The final proposed mixed waste treatment configuration balances the advantages and disadvantages of the configurations that were considered. It offers modest cost savings over the Draft Site Treatment Plan configuration, with some consolidation of treatment for certain waste streams but a substantial amount of onsite treatment.

A scenario was developed to evaluate how changes in siting assumptions could affect the Base Case cost estimates. Based on information in the Programmatic Environmental Impact Statement analysis, a more centralized approach than that identified in the Base Case could reduce overall costs by approximately $5 billion for storage, treatment, and disposal of wastes. Figure 5.11 shows a more decentralized approach than that identified in the Base Case, which could increase costs by $9 billion. Although the data in this alternative case are preliminary, and further evaluation is necessary, tentative conclusions can be made with respect to the implications of this type of analysis. For example, the Base Case assumes that low-level and low-level mixed waste will be disposed of at 6 sites. The decentralized scenario assumes disposal at 16 sites, which accounts for a considerable portion of the increased cost. The Department is working with State representatives to develop a siting configuration for low-level mixed waste

disposal facilities. Preliminary discussions have pointed out the importance to minimize waste shipments across State borders. Life-cycle cost and risk information being developed by the Department will be used in developing specific siting options. Obviously, trade-offs will need to be made between costs, risks, and public acceptability to reach agreement on configurations that are both acceptable and implementable from a cost and risk perspective.

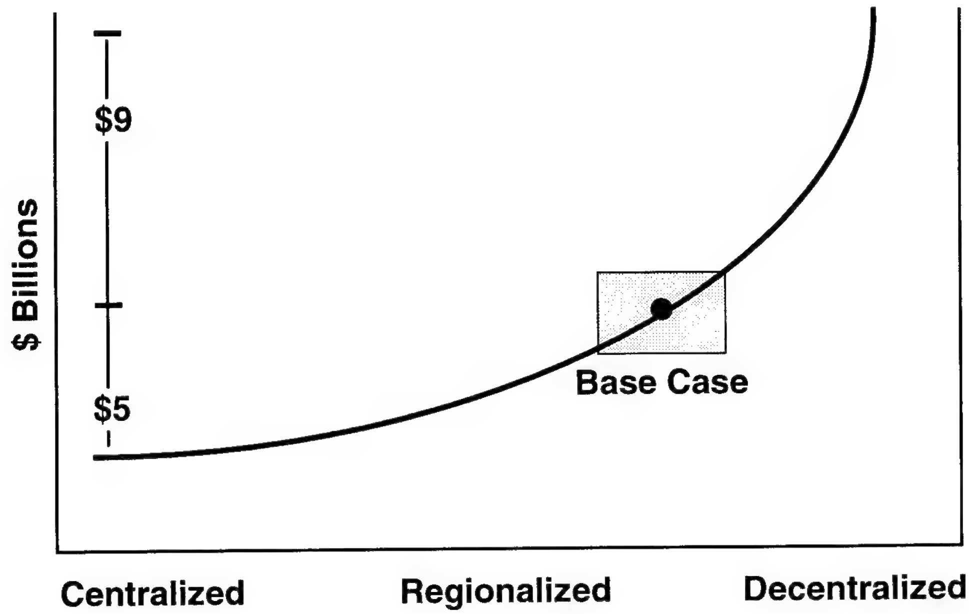


Figure 5.11. Base Case Comparison to Other Configuration Alternatives

6.0 Next Steps

The purpose of the Baseline Report is to clearly articulate the potential life-cycle cost and schedule of the Department of Energy's Environmental Management program. The report represents numerous perspectives on the Base Case estimate, together with the analysis of the alternative cases, the range of policy, technical, and management decisions facing the program, and indeed, the Nation. After considering economic factors, productivity improvements, and alternative cases, the range of life-cycle costs for the Environmental Management program is seen to be substantial. This range is depicted in Figure 6.1. Naturally, this range will narrow as the program matures. However, in the short term, the broad range of technical, economic, and policy uncertainties highlight the need for a broad public debate both nationally and locally regarding the future of the Environmental Management program.

Many significant decisions must be made over the next several years. Although this report is a starting point, much work needs to follow to ensure that these issues are effectively framed, that all interested stakeholders participate in the debate, and that data and methodologies supporting the analysis are continuously improved. Next steps should include the following:

- **Broaden the Range of Policy, Technical, and Management Issues Evaluated by the Baseline Report**: This report addresses, at a very general level, several key issues confronting the program. The policy analyses begun this year need to be more rigorous to make more-informed decisions—particularly in the areas of land use and residual contamination. New issues not addressed in this report, or that arise as a result of the information presented, need to be introduced into the debate—issues such as the impacts of varying program schedule and program prioritization based on risk. To achieve these ends, more focused data collection instruments and data quality objectives are necessary.

- **Improve the Life-Cycle Cost and Schedule Estimates**: This report is the first attempt by the Environmental Management program to develop a comprehensive life-cycle cost estimate. A number of lessons have been learned in the construction of these estimates. Appendix C, *Baseline Environmental Management Report Methodology,* offers some suggestions for improving the report methodology and data collection. More suggestions are anticipated from the review process.

- **Use the Baseline Report Tools to Address Ongoing Program Issues**: The 1995 report and the supporting data and analyses lay the foundation for evaluating program alternatives. The tools developed for this first report and the experiences gained in modeling and compiling these estimates should be routinely applied to ongoing program issues. We now recognize that program disconnects exist within installations and across the Department of Energy complex. Identifying inconsistencies is the first step to problem resolution. Continuous application of the tools will strengthen the model outputs and improve the quality of the tools.

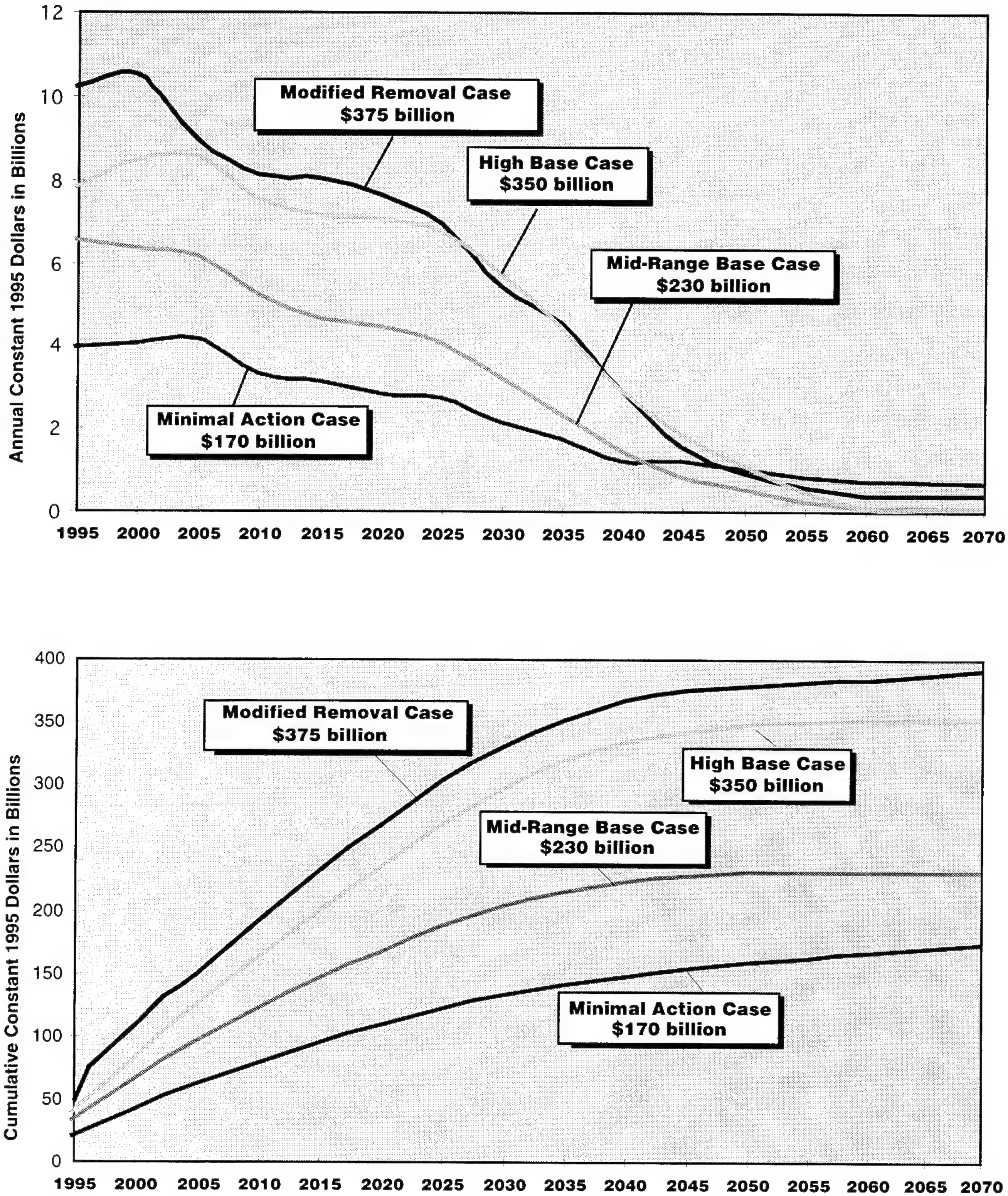


Figure 6.1. Potential Range of the Life-Cycle Cost Estimate

- **Include More Stakeholders in the Debate**: To date, neither a comprehensive, integrated total cost estimate nor a well-defined scope for the total Environmental Management program has been available. Until the results of this first effort are thoroughly evaluated by and feedback is received from the program's stakeholders, they must be considered preliminary. The assumptions, data, and methodologies used to integrate the program's components and extrapolate costs far into the future need rigorous scrutiny and debate. However, with the information provided in this report, a more informed debate on the future of the program is possible. The Department is committed to involving a wide range of stakeholders in these discussions in an effort to promote and inform broad-based citizen involvement in Government decisionmaking. Citizen views will be aggressively sought, especially at the local levels, to formulate subsequent Baseline Report cost estimates.

A. National Defense Authorization Act for FY 1994

APPENDIX A
National Defense Authorization Act for Fiscal Year 1994

Sec. 3153. Baseline Environmental Management Reports

(a) Annual environmental restoration reports

(1) The Secretary of Energy shall (in the years and at the times specified in paragraph (2)) submit to the Congress a report on the activities and projects necessary to carry out the environmental restoration of all Department of Energy defense nuclear facilities.

(2) Reports under paragraph (1) shall be submitted as follows:

(A) The initial report shall be submitted not later than March 31, 1995.

(B) A report after the initial report shall be submitted in each year after 1995 during which the Secretary of Energy conducts, or plans to conduct, environmental restoration activities and projects, not later than 30 days after the date on which the President submits to the Congress the Budget for the fiscal year beginning in that year.

(b) Annual waste management reports

(1) The Secretary of Energy shall (in the years and at the times specified in paragraph (2)) submit to the Congress a report on all activities and projects for waste management, transition of operational facilities to safe shutdown status, and technology research and development related to such activities and projects that are necessary for Department of Energy defense nuclear facilities.

(2) Reports required under paragraph (1) shall be submitted as follows:

(A) The initial report shall be submitted not later than June 1, 1995.

(B) A report after the initial report shall be submitted in each year after 1995, not later than 30 days after the date on which the President submits to the Congress the budget for the fiscal year beginning in that year.

(c) Contents of reports

A report required under subsection (a) or (b) of this section shall be based on compliance with all applicable provisions of law, permits, regulations, orders, and agreements, and shall:

(1) provide the estimated total cost of, and the complete schedule for, the activities and projects covered by the report; and

(2) with respect to each such activity and project, contain:

(A) a description of the activity or project;

(B) a description of the problem addressed by the activity or project;

(C) the proposed remediation of the problem, if the remediation is known or decided;

(D) the estimated cost to complete the activity or project, including, where appropriate, the cost for every five-year increment; and

(E) the estimated date for completion of the activity or project, including, where appropriate, progress milestones for every five-year increment.

(d) Annual status and variance reports

(1)(A) The Secretary of Energy shall (in the years and at the time specified in subparagraph (B)) submit to the Congress a status and variance report on environmental restoration and waste management activities and projects at Department of Energy defense nuclear facilities.

(B) A report under subparagraph (A) shall be submitted in 1995 and in each year thereafter during which the secretary of Energy conducts environmental restoration and waste management activities, not later than 30 days after the date on which the President submits to the Congress the budget for the fiscal year beginning in that year.

(2) Each status and variance report under paragraph (1) shall contain the following:

(A) Information on each such activity and project for which funds were appropriated for the fiscal year immediately before the fiscal year during which the report is submitted, including the following:

(i) Information on whether or not the activity or project has been completed, and information on the estimated date of completion for activities or projects that have not been completed.

(ii) The total amount of funds expended for the activity or project during such prior fiscal year, including the amount of funds expended from amounts made available as the result of supplemental appropriations or a transfer of funds, and an estimate of the total amount of funds required to complete the activity or project.

(iii) Information on whether the President requested an amount of funds for the activity or project in the budget for the fiscal year during which the report is submitted, and whether such funds were appropriated or transferred.

(iv) An explanation of the reasons for any projected cost variance between actual and estimated expenditures of more than 15 percent or $10,000,000, or any schedule delay of more than six months, for the activity or project.

(B) For the fiscal year during which the report is submitted, a disaggregation of the funds appropriated for Department of Energy defense environmental restoration and waste management into the activities and projects (including discrete parts of multiyear activities and projects) that the Secretary of Energy expects to accomplish during that fiscal year.

(C) For the fiscal year for which the budget is submitted, a disaggregation of the Department of Energy defense environmental restoration and waste management budget request into the activities and projects (including discrete parts of multiyear activities and projects) that the Secretary of Energy expects to accomplish during that fiscal year.

(e) Compliance tracking

In preparing a report under this section, the Secretary of Energy shall provide, with respect to each activity and project identified in the report, information which is sufficient to track the Department of Energy's compliance with relevant Federal and State Regulatory milestones.

(Public Law 103-160, Div. C, Title XXXI, §3153, Nov. 30, 1993, 107 Stat. 1950., Codified at 42 a.s.c. 7274k)

B. The Nuclear Weapons Production Process

Appendix B

APPENDIX B
The Nuclear Weapons Production Process

Introduction

The production of nuclear weapons requires special technologies invented for the Manhattan Project. It also requires special materials: highly enriched uranium and plutonium. Both are made, by different processes, from naturally occurring uranium ore. Mining uranium ore is thus the first link in a chain of complex processes that eventually produces a nuclear weapon.

Although plutonium and uranium are both essential parts of modern nuclear weapons, it is possible to make nuclear weapons by using one or the other material alone. In fact, the first generation of atomic weapons did so. Early nuclear weapons were of two types: (1) gun-type bombs using two masses of highly enriched uranium, forced together very quickly to assemble a "critical mass" that would sustain a nuclear chain reaction and subsequent explosion; and (2) implosion bombs using high explosives to squeeze together a sphere of plutonium very quickly and symmetrically into a critical mass to attain a nuclear explosion. The "Little Boy" dropped on Hiroshima was a uranium gun-type weapon, while the bomb dropped on Nagasaki was a plutonium implosion bomb. As designs for nuclear weapons improved and advanced, a new generation of bombs—thermonuclear weapons—evolved. Most modern weapons use both plutonium and uranium.

There is another essential material in most nuclear weapons: tritium, a radioactive gas, produced by bombarding lithium with neutrons in a reactor. Tritium is used to boost the explosive power of many modern weapons.

Special Nuclear Materials

In nature, more than 99 percent of the atoms in uranium have an atomic weight of 238. From this, the remaining 1 percent, a particular atomic form, or isotope, with a weight of 235 must be physically separated in sufficient quantities to sustain a nuclear chain reaction--either for generating electrical power or, at much higher concentrations, for explosives.

To separate sufficient quantities of uranium-235 requires enormous amounts of energy and the meticulous operation of large, complex separation methods were pursued simultaneously: electromagnetic separation in the "Calutron" (California University Cyclotron) and gaseous diffusion. Facilities for both were built at the Oak Ridge Reservation in Tennessee. Since then, however, gaseous diffusion has generally been used in the United States to enrich uranium. The process involves a series of vast structures designed to drive gaseous uranium at controlled temperatures and pressured through miles of filters that gradually collected uranium-235 atoms in increasing concentrations--a process called "uranium enrichment." Two additional diffusion plants were built in Ohio and Kentucky in the 1950s.

The highly enriched uranium (more than 20 percent uranium-235, and typically more than 90 percent) thus produced is used in nuclear weapons. Low-enrichment uranium, consisting of less than 20 percent uranium-235, is nearly impossible to make bombs with, but is used as fuel for nuclear reactors. The uranium-238 that is removed in the enrichment process is called "depleted uranium." It is used to make plutonium; it is also used in some nuclear weapon parts, as radiation shielding, in tank armor, and in armor-piercing bullets.

Scientists knew they could avoid the trouble and expense of physically enriching uranium if they could produce another nuclear material that could be chemically separated from impurities for use in bombs. That material was plutonium-239—an element that is created in nuclear reactors. In the fuel for these production reactors, uranium-235 splits into a host of radioactive by-products and releases neutrons. The neutrons bombard the uranium-238 in the reactor, transforming it into the heavier element plutonium.

Plutonium, like uranium, is a mix of several isotopes. Material rich in the isotope plutonium-239 is referred to as "weapons-grade plutonium." After plutonium-239 has been created in the reactor, workers must separate it from the uranium and the radioactive byproducts (fission products) in a reprocessing plant. This plant dissolves irradiated uranium in acid and then extracts the uranium and plutonium, leaving behind a highly radioactive liquid known as high-level waste.

Because radiation levels inside a procession plant are very high, the plant must be heavily shielded and operated by remote control to protect workers and the environment.

Uranium Mining and Milling

Most of the uranium ore for the first atomic bombs came from rich deposits in Africa and Canada, but more than 400 mines eventually opened in the United States. After World War II, uranium mining in the United States expanded dramatically, from 38,000 tons of ore in 1948 to 5.2 million tons in 1958, nearly all of which was used for nuclear weapons. One ton of uranium ore yields only a few pounds of uranium metal. The United States mined about 60 million tons of ore to produce uranium for nuclear weapons production. This activity produced large volumes of a sandlike byproduct called "mill tailings," which contain both toxic heavy metals and radioactive radium and thorium. For each 2 pounds of plutonium made for the U.S. arsenal, miners took roughly 1,000 tons of uranium ore. In the mills, the ore was crushed, and the uranium metal was leached out with acid. The result was a dry, purified concentrate called "yellowcake."

Because uranium mills typically piled tailings outdoors without covers or containment, some material was spread by wind and water. And unfortunately large volumes of the tailings were used in some areas as construction materials for pavements and houses. The primary hazard of these tailings is the emission of radon. In 1978, the Congress passed a law requiring that the tailings be adequately stabilized to protect the environment and human health.

Uranium mills, like those at Monument Valley in Arizona and Grand Junction or Rifle in Colorado, shipped the yellowcake to refineries at the Fernald Plant in Ohio and to Weldon Spring, Missouri, to refine the concentrate into forms suitable for different roles in weapons production. The refineries discharged uranium dust into the air, contaminating soils, surface waters, and ultimately ground water. From the refineries, the refined uranium went to enrichment plants at Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio.

Uranium Enrichment

To make highly enriched uranium, the enrichment plants used a complicated process to remove and separate most of the rare uranium-235 from the more-abundant uranium-238 isotope. The highly enriched uranium produced in the United States between 1943 and 1964 was used to make nuclear weapons. Most of the material fed into the enrichment plants came out as depleted uranium, also called enrichment "tails." Many thousands of tons of depleted uranium are still stored in cylinders at Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. Inadequate waste management at enrichment plants over the years caused

extensive environmental contamination not only with radioactive materials but also solvents, polychlorinated biphenyls, heavy metals, and other toxic substances.

Fuel and Target Fabrication

Before uranium was used in nuclear weapons production, it was converted into metal. Workers at the Fernald uranium foundry in Ohio converted hundreds of tons of uranium hexafluoride gas into "green-salt" crystals. These crystals were blended with magnesium granules and cooked in a furnace. The mixture ignited, converting the green-salt crystals into uranium metal. Some of this metal was made into reactor fuel or targets for plutonium production at Hanford in southeastern Washington, and the Savannah River Site in South Carolina. Additional uranium metal was converted into alloys for fabrication into weapons components at the Rocky Flats Plant in Colorado and the Y-12 Plant in Oak Ridge, Tennessee. The main environmental impacts of these operations were unintended releases of uranium dust and chemicals leaking from landfills.

Reactor Irradiation

The uranium fuel slugs were used to power the 14 plutonium production reactors at the Hanford and Savannah River sites. The targets were irradiated in these reactors to produce plutonium (about 100 metric tons in total). Because only a small fraction of the uranium in fuel and targets could be converted to plutonium during each cycle through a reactor, workers at Hanford and Savannah River handled thousands of tons of uranium. While the reactors were operating, their main environmental legacy was highly radioactive spent fuel and irradiated targets, which, when reprocessed as described below, yielded high-level radioactive waste. Now that the reactors are shut down, they must be stabilized and maintained until they can be decommissioned.

Chemical Separations

The irradiated fuel and targets discharged from the Hanford and the Savannah River reactors contained hundreds of different radioactive isotopes, collectively called "fission products." This waste had to be separated from the uranium and plutonium. Chemical processes for this separation were developed, and separation "canyons" (also known as "reprocessing plants") were built at the Idaho National Engineering Laboratory, the Savannah River Site, and the Hanford Site. Over a period of 40 years, these plants generated 105 million gallons of highly radioactive and hazardous chemical waste—enough to fill a 1,000-foot-

long supertanker. They also produced billions of gallons ofwastewater that contained small amounts of radionuclides and chemicals. Because it was discharged directly to the ground, this wastewater caused widespread contamination.

The high-level waste generated in chemical separations contains almost 99 percent of all radioactivity present in byproducts and waste generated by nuclear weapons production. It also contains some long-lived radioactive elements that could pose environmental risks for tens of thousands of years. As discussed in Section 2.2, none of this waste has been disposed; it remains stored in steel tanks and must be maintained and monitored until it can be converted into a solid form suitable for permanent disposal at a geologic repository. The earliest projected date for the operational start of this repository is 2016.

Another legacy of the chemical separation process is contaminated facilities. The enormous buildings used for this purpose at the Hanford Site in Washington and at the Savannah River Site in South Carolina are so contaminated with radioactive materials that decontamination must be done by remote control to protect workers.

Fabrication of Weapons Components

Most plutonium from the reprocessing plants went to the Rocky Flats Plant in Colorado to be machined into warhead components. The weapons laboratories—for example, the Los Alamos National Laboratory in New Mexico—also used some plutonium to make and test prototype designs for weapons. Waste from this step in the process is mostly plutonium-contaminated (transuranic) waste, which requires long-term isolation, or low-level radioactive waste; in addition to radioactivity, both of these wastes may contain hazardous chemicals and thus by law require special treatment or storage. Large quantities of plutonium in various forms were left in the plant when the Rocky Flats Plant was shut down, and there is widespread contamination at the site.

Weapons Assembly and Maintenance

Factories in several States (mainly Florida, Missouri, and Ohio) contributed nonnuclear components for the final assembly of nuclear weapons. Final assembly occurred primarily near Amarillo, Texas, at the Pantex Plant. The assembly process generated very little radioactive waste, but local areas of soil were contaminated with high-explosives waste, fuel and oil leaks, and the like. The Pantex Plant now disassembles warheads that have been retired from the Nation's arsenal and is responsible for storing most of our plutonium components. The enriched-uranium

components are stored primarily at the Y-12 Plant at Oak Ridge, Tennessee. Interim storage and ultimate disposition of surplus nuclear weapons materials pose a number of serious challenges, such as worker and public safety and security against potential theft.

Research, Development, and Testing

Research, development, and testing have been a critical part of the nuclear weapons enterprise. Two national laboratories, at Livermore, California, and Los Alamos, New Mexico, devoted their expertise to nuclear weapons development and testing. Sandia National Laboratories in Albuquerque, New Mexico, and Livermore, California, worked on the nonnuclear components for nuclear warheads and designs for coupling the warheads to bombs and missiles.

The United States tested more than 1,000 individual nuclear devices in atmospheric, underwater, and underground tests. Most of the tests were conducted in Nevada. The United States stopped atmospheric testing in 1963 and has not conducted any nuclear explosion tests since 1992. Nuclear explosion tests were also conducted in Colorado, New Mexico, Mississippi, and Alaska for non-weapons purposes—to explore the potential use of nuclear explosions for extracting natural gas and digging harbors. Waste from research, development, and testing consists mostly of low-level waste as well as large volumes of contaminated soil and debris. The testing of nonnuclear components left contamination with high-explosives materials and other chemicals.

C. Baseline Report Methodology

APPENDIX C
Baseline Report Methodology

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Section **Page**

C.0 Introduction

The mandate from Congress in the FY 1994 National Defense Authorization Act presented an immense challenge. The Department of Energy was asked to provide a complete life-cycle cost estimate, broken out by specific projects and activities, at a time when the mission of the Department and the scope and objectives of the Environmental Management program are incompletely defined. Three fundamental questions must be answered in order to be able to develop a life-cycle cost estimate (Table C.1):

Table C.1
Fundamental Questions Affecting Environmental Management Program Life Cycle Costs

- What are the environmental problems or challenges facing the Environmental Management program?
- What are the potential solutions to these problems?
- What are the ultimate goals or end-states that the Environmental Management program is attempting to achieve?

None of these fundamental questions can be answered fully at present. In some cases, basic information is insufficient to fully understand the nature of problems, solutions, or ultimate goals. In other cases, the answers to these questions are evolving. In all cases, the answers must be obtained through a democratic process involving the Department, Federal and state regulators, the Congress, and citizens.

Defining the environmental problems and challenges is particularly difficult because the nature and extent of environmental contamination has not been characterized fully. Moreover, prior to publication of this report, existing data were not yet assembled in one place and integrated in one comprehensive framework. When the problems eventually are identified fully, a series of policy, regulatory, and technical decisions and constraints will affect the ultimate goals or end-states that the Environmental Management program must achieve as well as the range of potential solutions available. The total cost and schedule for the Environmental Management program ultimately will depend on the sum total of the paths each problem takes as it moves through the solution phase to the ultimate end-state. A host of policy, regulatory, and technical decisions, along with constraints and end-states, will determine the final cost and schedule estimates.

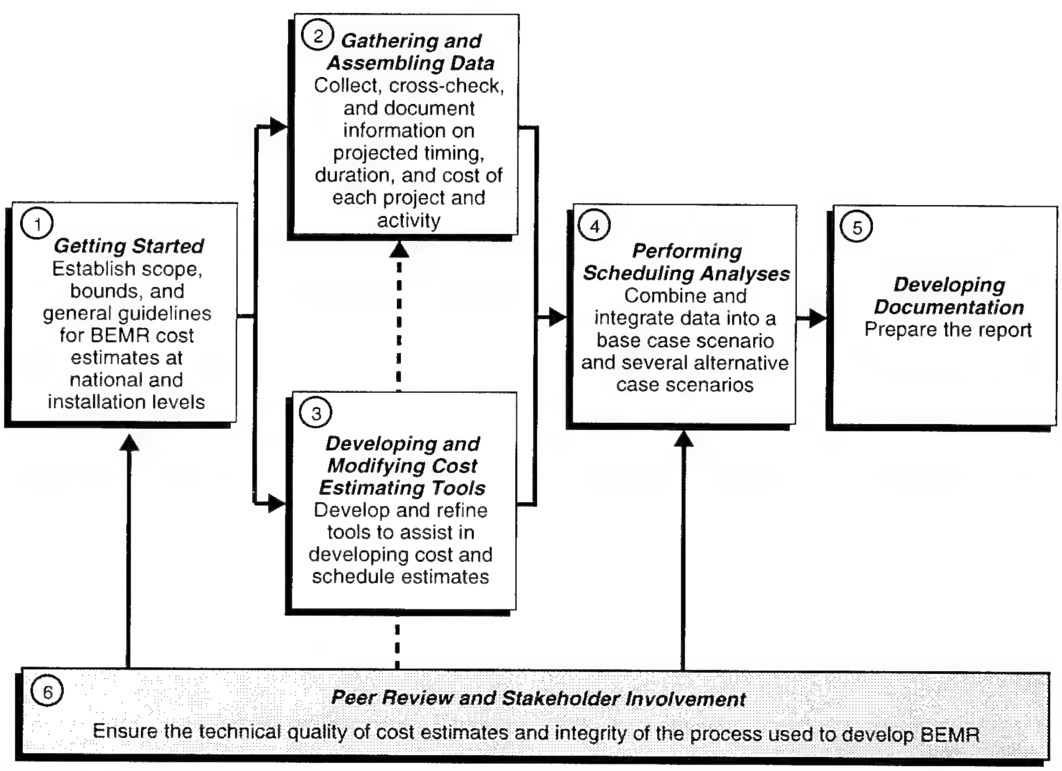
The challenge facing the Department of Energy was to provide a credible, comprehensive estimate of the total cost and schedule for the Environmental Management program when the problems have not been characterized fully and few of the key decisions affecting solutions and end-states have been made. As a consequence, the Department had to develop a number of assumptions about the future of the Environmental Management program and a number of new approaches and tools for developing this cost and schedule estimate. These assumptions had to reflect technically feasible solutions and reasonable end-states (e.g., future

land uses). At the same time, these assumptions could not be seen as prejudicial to ongoing decision-making processes (e.g., renegotiating compliance agreements with the Environmental Protection Agency and states, developing plans for siting low-level mixed waste treatment facilities under the Federal Facility Compliance Act).

With this methodology, the Department of Energy has attempted to create a framework for estimating cost and schedule that (a) incorporates current understanding of problems, solutions, and ultimate end-states; (b) is understandable to Congress and citizens; and (c) is flexible enough to incorporate changes in an efficient and simple manner. The methodology also allows explicit re-evaluation of cost and schedule estimates as key decisions (e.g., new regulations, change in preferred end-states) or assumptions (e.g, availability of new technologies) change over time.

The assumptions, approaches, and tools that comprise the methodology reflect the immense challenges outlined above. The overall process used by the Department can be divided into six general steps (Figure C.1). Each of these steps is described in a separate subsection below.

Figure C.1 Steps in the General Methodology



C.1 Getting Started

C.1.1 Setting Assumptions

This section presents the approach used to develop assumptions for cost and schedule estimates. The Department developed assumptions at three levels: general assumptions to guide development of this report, national assumptions to be applied uniformly across all of the Department of Energy installations, and installation-specific assumptions.

Table C.2
General Assumptions for this Report

Legal Requirements — all cost and schedule estimates will assume that Department of Energy actions will be consistent with existing legal agreements and will be in compliance with existing laws and regulations.

Ongoing Decision Processes — all cost and schedule estimates will be as consistent as possible with ongoing negotiations, decision-making processes, and related studies.

Local Visions of the Future — all cost and schedule estimates will, to the extent possible, reflect each installation's own views of their likely future.

Estimates, not Decisions — the cost and schedule estimates presented in this report do not reflect decisions reached unilaterally by the Department.

General assumptions — The Department established several overarching, general assumptions to guide development of this report (Table C.2). The primary assumption is that all Department of Energy activities will be in full compliance with all legal agreements (e.g., Tri-party compliance agreements) and all applicable Federal, state, and local laws and regulations. For example, cost estimates for all projected remedial actions assume that remedial technologies will be designed to meet all applicable or relevant and appropriate regulations and will be implemented in compliance with all worker safety regulations (e.g., Occupational Safety and Health Administration requirements). Similarly, all projected waste management facilities are assumed to be designed, permitted, operated, and closed in full compliance with Resource Conservation and Recovery Act requirements and worker safety regulations.

The second general assumption is that all cost and schedule estimates will be as consistent as possible with ongoing decision-making processes. The Department currently is engaged in a number of negotiations, discussions, and studies in support of key decisions affecting solutions or desired end-states, including:

- Federal Facility Compliance Act negotiations to determine where mixed low-level waste treatment facilities will be located;
- The Future Use initiative aimed at determining local stakeholders' preferred future land uses for Department of Energy installations;
- Studies leading to National Environmental Policy Act documentation such as the Waste Management Programmatic Environmental Impact Statement, installation-specific environmental impact statements, and the Spent Nuclear Fuel Programmatic Environmental Impact Statement; and

- The process examining how the Department of Energy can meet compliance agreements under projected Congressional funding limits.

> *Many assumptions used for this report will become out of date as ongoing decision-making processes evolve and will need to be revisited each year.*

Ideally, this report should reflect the key policy decisions reached via these democratic processes. However, many of these processes will not achieve final decisions for several months or years, and the directions that these processes are leading is expected to change any number of times as these processes evolve. As a consequence, the specific assump-tions used to develop cost and schedule estimates for this report (e.g., future land use, locations of waste management facilities) reflect the current state of these processes "frozen" at a particular point in time. Therefore, it is expected that this report will rapidly become out of date with respect to the current state of these processes, and assumptions in future reports will differ from those in this report.

The third general assumption is that the assumptions used to develop cost and schedule estimates for this report will reflect each installation's own vision of the future. The inherent uncertainties associated with predicting activities several decades into the future make it difficult for anyone to accurately estimate the total life cycle cost and schedule for the Environmental Management program. The best current understanding of potential future developments at each installation, limited as it may be, is likely to be held by those individuals that live and work at or nearby these facilities.

> *The assumptions and resulting cost and schedule estimates presented in this report are not, and should not be interpreted as, final decisions, except where these reflect existing legal agreements.*

The final general assumption is that this report is not a decision document. Given the fundamental uncertainties and gaps associated with the problems, solutions, and end-states, the Department recognized that numerous assumptions would be required in order to meet the Congressional mandates set forth in the National Defense Authorization Act. The FY 1994 Department also recognized that these assumptions, and the resulting cost and schedule estimates, could be interpreted as final decisions. Therefore, the assumptions used to develop this report, and the cost and schedule resulting from implementing these assumptions, are developed solely to meet the Congressional mandates for this report, except where these assumptions, costs, and schedules reflect conditions set forth in Records of Decision, compliance agreements, and other legal agreements. The Department fully expects assumptions and cost and schedule estimates to change in future reports as new information becomes available and ongoing decision-making processes evolve.

National assumptions — Certain assumptions were applied uniformly across all of the Department of Energy installations. These assumptions dealt with issues such as projected funding levels; where treatment, storage, and disposal of low-level mixed waste, low-level waste, and transuranic waste would occur; and when the geologic repository and the Waste Isolation Pilot Plant are expected to accept waste for disposal. Most of the national assumptions were developed at Headquarters based on the current status of ongoing decision processes (e.g., negotiations with states under the Federal Facility Compliance Act), current Environmental Management program plans, and discussions with the Office of Management and Budget. National assumptions were reviewed by each field office and modified as necessary.

Installation-specific assumptions — Specific assumptions regarding how the Environmental Management program is likely to unfold at each installation were provided by each installation. These assumptions dealt with issues such as expected future land use and the likely types of remedial technologies to be used for particular problems. Installation-specific assumptions were reviewed at Headquarters and modified as necessary.

C.1.2 Defining Environmental Management Program Elements, Activities, Projects, and Cost Categories

The cost and schedule estimates presented in this report represent a significant departure from the way that the Environmental Management program has been described to date. The FY 1994 National Defense Authorization Act required the Department to provide a description of each project and activity to be performed by the Environmental Management program. Congress, however, did not define or provide guidance for what should be considered a project or activity. One of the critical first tasks in developing this report was to develop an installation-by-installation list of all proposed activities and to describe the projects and tasks that would be included in these activities.

C.1.2.1 General Definitions and Criteria

Activities — The Department developed several guidelines and criteria for defining activities. The primary objectives were to ensure that cost and schedule estimates were linked to real, definable problems. At the same time, activities needed to be limited in number to keep the analysis manageable. Activities thus had to meet several criteria (Table C.3). Activities had to be tangible entities linked to geographically identifiable problems or sites. They also had to be large enough to address real problems and represent significant cost. To facilitate schedule estimates, activities had to have a definable beginning and end. Finally, individual

Table C.3 Criteria for Defining Activities
Tangible entities linked to geographically identifiable problems or sites
Large enough to address real problems and represent significant cost
Definable beginning and end
Able to be linked to existing budget breakdowns and planning tools

installations had to have the ability to crosswalk activities with existing budget breakdowns and planning tools. Using the above criteria, each installation developed a proposed list of activities for this report. These activity lists were reviewed by Headquarters staff and revised as needed. Lists and descriptions of specific activities are provided in the individual installation summaries presented in Volume II of this report.

Environmental restoration activities generally represent discrete, identifiable geographical portions of installations (or entire small installations). For nuclear material and facility stabilization activities, large facilities are listed as discrete activities, while smaller facilities are grouped together by facility category and geography. Waste management activities are defined as treatment, storage, and disposal of high-level waste, spent nuclear fuel, low-level waste, low-level mixed waste, and transuranic waste at each installation where the waste type is present. Hazardous waste and sanitary waste are considered activities, but have not been divided into treatment, storage, and disposal. Directly funded landlord activities are listed as discrete activities at each applicable installation. Program management is listed in two ways. Each installation lists a discrete program management activity associated with environmental restoration, nuclear material and facility stabilization, and waste management. In addition, a discrete, national program management activity is listed for Headquarters. Program direction, technology development, and transportation management also are listed as a discrete Headquarters activities. However, most of the funding for these activities, although budgeted at Headquarters, is transferred to the field.

Projects — The Department subdivided environmental restoration activities into separate projects ("subprojects") to assist in developing cost and schedule estimates. Each separate subproject represents an individual unit for which regulatory decisions are made at an installation (generally comparable to a Superfund Operable Unit). This allowed the Department to re-schedule environmental restoration activities at a finer grain than would have been possible at the activity level. Subprojects also made it easier to estimate the actual types of work that might need to be performed for each activity and to crosswalk activities with existing budget breakdowns and planning tools. The Department also provides a listing of waste management projects to identify significant facilities at major installations.

Cost Categories — To facilitate understanding of how cost and schedule estimates were prepared, the Department developed an initial list of cost categories for the various elements that make up the Environmental

Management program (Table C.4). Note that *these cost categories do not correspond directly to current program budget categories.* These categories were reviewed by Headquarters staff and revised as needed. Each individual installation then provided a written description of the types of tasks included in each of their activities. These descriptions are provided in the individual installation summaries presented in Volume II of this report. A description of each cost category is provided below.

Table C.4
Program Elements and Cost Categories

Environmental Restoration	*Technology Development*
Assessment	*Landlord*
Remedial actions	*Program Management*
Decommissioning	Installations
Long-term operation and maintenance	Headquarters
Nuclear Material and Facility Stabilization	*Program Direction*
Surveillance and maintenance	*Transportation Management*
Stabilization	
Waste Management	
Waste treatment	
Waste storage	
Waste disposal	

C.1.2.2 Environmental Restoration Cost Categories

Environmental restoration activities are carried out to ensure that potential exposures to radionuclides and other contaminants present in environmental media and surplus facilities are eliminated or reduced to prescribed levels deemed tolerable through formal agreement with regulators. The major cost categories for environmental restoration activities are assessment, remedial actions, decommissioning, and long-term surveillance and maintenance.

Assessment involves all activities required to identify and characterize release sites or facilities and reach a formal agreement with regulators regarding appropriate further actions (e.g., Superfund Records of Decision). Specific tasks include reviewing historical records; physically assessing current conditions at the release site or facility; collecting and evaluating media samples to identify the nature and extent of contamination; assessing current and future risks to human health and the environment; developing and evaluating the feasibility of potential

decommissioning or remedial options (including no action); conducting appropriate public involvement activities; and preparing, reviewing, and revising all reports and documents required by applicable regulations.

Remedial actions follow assessment and involve all activities required to implement further actions deemed appropriate through formal agreement with regulators. There are three general types of remedial actions: active remediation, containment, and no further action. Active remediation of most contaminants, including radionuclides, involves excavating or extracting contaminated media and one or more of the following: treatment to remove contaminants from the medium, placing the contaminated medium or by-products in appropriate containers for shipment to treatment or disposal sites, and/or directly disposing of the contaminated medium or by-products in an appropriate disposal facility. In-place destruction (e.g., bioremediation) may be possible for some organic contaminants. Containment involves leaving contaminants in place and constructing physical barriers (e.g., caps, slurry walls) or implementing interception strategies (e.g., pumping ground water) to prevent further migration of contaminants. No further action involves leaving contaminants in place with no active steps to prevent further migration.

> *Remediation efforts cannot destroy radionuclides and other inorganic chemicals. These contaminants must ultimately be contained in place or transferred to a permitted disposal site.*

Decommissioning activities involve the safe decontamination or complete dismantlement of surplus facilities that have been stabilized. The contents of these facilities are primarily reactors, hot cells, processing plants, storage tanks, research equipment, and other structures. Related tasks include surveillance and maintenance, assessment and characterization, environmental documentation review, waste disposal, and closeout.

Long-term operation and maintenance is conducted to ensure that the selected remedies continue to provide the level of protection for human health and the environment that is specified in formal agreements with regulators. These activities are required for all remedies involving containment or no further action and may be required for long-term remediation strategies (e.g., ground water pump-and-treat operations) and following completion of decommissioning actions. Specific tasks may include compliance monitoring to ensure that the remedial technologies remain effective as well as surveillance to ensure that physical access to restricted areas is prevented.

C.1.2.3 Nuclear Material and Facility Stabilization Cost Categories

Nuclear material and facility stabilization activities involve facilities that the Department has deemed surplus as they no longer are needed to meet mission objectives (e.g., research, waste management, nuclear weapons

production or dismantlement). These activities are carried out to ensure that surplus facilities are secure and in a safe shutdown condition pending their ultimate disposition, which could range from demolition to further cleanup and commercial reuse. The major cost categories for nuclear material and facility stabilization activities are surveillance and maintenance and stabilization. Although not costed in this initial report, future activities within this scope will include the management and safeguarding of special nuclear materials.

Surveillance and maintenance activities involve all actions required to ensure adequate security of surplus facilities pending their ultimate disposition. Specific tasks include maintaining fences and other access barriers and providing on-site surveillance, environmental monitoring, repairs, and other routine maintenance. Surveillance and maintenance continues prior to, during, and after stabilization until the ultimate disposition has been completed.

Stabilization activities involve elimination of immediate safety and environmental hazards as well as removal of most contaminants within the facility. Specific tasks include removing equipment and stock chemicals; cleaning out pipelines, holding tanks, and process vessels; and removing reactor cores.

C.1.2.4 Waste Management Cost Categories

Waste management activities involve the safe and efficient treatment, storage, and disposal of wastes and other related materials managed by the Department of Energy. Most of this effort involves the design, permitting, construction, operation, maintenance, stabilization, and clean closure of treatment, storage, and disposal facilities. The wastes come from three primary sources: existing inventories from past generation and new waste generated by ongoing Departmental missions; wastes derived from environmental restoration activities; and wastes derived from nuclear material and facility stabilization activities. The Environmental Management program manages high-level, transuranic, low-level mixed, low-level, hazardous, and sanitary waste as well as the Department of Energy inventory of spent nuclear fuel. The major cost categories for waste management activities are treatment, storage, and disposal.

Waste Management activities include the design, permitting, construction, operation, maintenance, stabilization, and clean closure of facilities for treating, storing, and disposing of wastes.

Treatment activities involve the application of a wide variety of technologies such as incineration, vitrification, and grouting that transform wastes into materials suitable for disposal. In addition to constructing, operating, maintaining, and closing waste *treatment*

facilities, specific tasks include characterizing wastes to determine appropriate handling procedures, and packaging and transporting wastes to appropriate treatment facilities, or disposal facilities.

Storage activities are undertaken if no appropriate treatment or disposal facility is available for a given volume of waste. In addition to constructing, operating, maintaining, and closing *storage* facilities, specific tasks include characterizing wastes to determine appropriate handling procedures, and packaging and transporting wastes to appropriate treatment or disposal facilities.

Disposal activities involve placing post-treatment materials into appropriate landfills, repositories, or other engineered structures and providing adequate security, surveillance, and maintenance to ensure that contaminants are not released from these facilities into the environment. In addition to construction, operation, and maintenance of *disposal* facilities, specific tasks include providing on-site surveillance, environmental monitoring, repairs, and other routine maintenance.

C.1.2.5 Technology Development Cost Categories

Technology development activities include managing and directing focused, problem/solution-oriented technology development programs to support environmental restoration, nuclear material and facility stabilization, and waste management activities. These activities do not include basic science research. Technologies are designed to facilitate compliance, minimize waste generation, and decrease site cleanup costs. The Environmental Management program has focused on five major remediation and waste management problem areas for action on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations (Table C.5). A major goal of the targeted areas is to enhance the commercialization and implementation of new technologies to reduce costs and provide a world-wide leadership role for the U.S. in environmental remediation. In the future, the Department may identify and add other areas to ensure that research and technology development programs remain focused on the most pressing remediation and waste management needs. Costs for technology development activities are shown in this report at Headquarters. However, approximately 91 percent of program funding for these activities is transferred to field operations.

Table C.5
Technology Development Focus Areas

Plume Containment and Remediation — Many contaminated Department of Energy sites have not been adequately characterized and current treatment processes, especially for contaminated ground water, are slow and expensive. This area focuses on improving characterization and data interpretation methods, containment systems, and in-place treatment of groundwater and soils.

Mixed-Waste Characterization, Treatment, and Disposal — The Department faces major technical challenges in the management of low-level mixed waste. Current waste management regulations require extensive, hence costly, waste characterization before treatment. The Environmental Management program is developing technology to more effectively characterize, retrieve, treat, and dispose of mixed waste.

Radioactive Waste Tank Remediation — Across the complex, there are hundreds of large storage tanks containing hundreds of thousands of cubic meters of high-level and other radioactive wastes. Primary areas of concern include deteriorating tank structures that pose risks due to leaking. This effort focuses on developing safe, reliable, cost-effective methods for characterizing, retrieving, treating, and disposing of radioactive tank waste.

Landfill Stabilization — Many landfills require interim containment prior to final remediation because contaminants are migrating from these structures. This area focuses on developing in-place methods for containment, as well as developing retrieval systems and off-site treatment systems that reduce worker exposure and the quantity of secondary waste.

Nuclear Material and Facility Stabilization, Decommissioning, and Final Disposition — The reduction in nuclear weapons production along with the continued aging of the complex has generated the need to disposition numerous contaminated facilities. This area focuses on enhancing technologies for decontaminating materials and educating the public on the relatively low risks associated with the recovered materials. These efforts promote recovery, recycling, and/or reuse of these resources. The Environmental Management program also is working on material removal, handling, and processing technologies to enhance worker safety and reduce costs.

Landlord activities involve the physical operation and maintenance of Department of Energy installations. Specific tasks vary from installation to installation but generally include provision of utilities, maintenance, and general infrastructure for the entire installation.

C.1.2.6 Cost Categories for Other Environmental Management Program Elements

Other Environmental Management program elements include landlord, program management, program direction, and transportation management (see Table C.4).

Landlord Activities involve the physical operation and maintenance of Department of Energy installations. Specific tasks vary from installation to installation but generally include provision of utilities, maintenance, and general infrastructure for the entire installation.

Program Management activities include planning, monitoring, and reporting of ongoing activities, cost/schedule tracking, clerical, and other administrative support. This cost category also includes grants to states and localities. Examples of support costs include government furnished equipment and laboratory upgrades, and those associated with treatability studies, prevention of contamination dispersion studies. Program management costs include management of the Environmental Management program at each installation as well as nation-wide management of the Environmental Management program at Headquarters. Program management includes program support, which includes general technical contractor support services for all Environmental Management Headquarters elements, special projects of immediate concern, and other projects that arise during the course of a fiscal year. Approximately 70 percent of program support funding budgeted at Headquarters is transferred to field operations.

Program Direction activities includes all federal full-time equivalents at Headquarters and the field offices. Program direction provides funding for salaries, and benefits. Costs for program direction activities are shown in this report at Headquarters. However, approximately 75 percent of program direction funding budgeted at Headquarters is transferred to field operations.

Transportation Management activities include Department-wide development and implementation of effective strategies, techniques, methods, and policy guidance for the safe, secure, efficient, and cost-effective transportation of Department of Energy materials, including radioactive materials, hazardous substances, and hazardous and mixed wastes. Activities include managing the transportation of materials between Department of Energy installations; packing, shipping, and handling materials prior to shipping; container safety; logistics; transportation communication systems; and monitoring and guidance for installation-specific transportation support.

C.1.3 Limitations and Next Steps

The basic limitation in setting assumptions for a life cycle cost and schedule estimate is that most specific assumptions evolve over time. The logistics of assembling and analyzing data, and writing and publishing a report based on these data, require "freezing" assumptions at a certain point in time. As assumptions continue to change, cost and schedule estimates will be changed to reflect those changes.

Several ongoing decision-making processes have the potential to alter many of the key assumptions underlying this cost and schedule estimate. Many Department of Energy installations are currently engaged in

processes to determine preferred land use options. Negotiations under the Federal Facility Compliance Act also are underway to determine where low-level mixed waste treatment facilities will be located. A variety of environmental impact statements (EISs) are being prepared, including the Spent Nuclear Fuel Programmatic EIS, the Waste Management Programmatic EIS, and installation-specific EISs. As these decision-making processes move forward, changes in national and installation-specific assumptions will be required. Future reports will incorporate these changes to the extent possible.

In developing the activities and cost categories for this report, the Department has attempted to describe clearly the scope and magnitude of the Environmental Management program. In most cases, activities represented discrete sets of problems and projected solutions, and cost categories mapped discretely into activities. However, some approximation and apportioning was necessary to map existing budget breakdowns into these new categories. For subsequent reports, the Department will evaluate the effectiveness of the structure developed for this report, both for describing the Environmental Management program, and for developing cost and schedule estimates, and revise it as needed.

C.2 Gathering and Assembling Data

The nuclear weapons complex is a sprawling industrial complex of production, fabrication, and research facilities located on thousands of square miles of Federal lands. Nuclear weapons production has left a legacy of widespread environmental contamination. Millions of cubic meters of radioactive and hazardous wastes have been buried throughout the complex, and this has resulted in extensive contamination of soil, sediments, surface waters, and ground waters. The Environmental Management program has responsibility for more than 10,000 individual "release sites" (separate structures or portions of environmental media containing contaminants), and more than 3,500 separate facilities. Waste treatment may need to occur at 34 separate installations. Clearly, the Department was faced with an enormous task in defining the activities necessary to complete the Environmental Management program and estimating costs for these activities.

The need to provide a basis for policy analyses (e.g., how total cost would change if annual funding went up or down) required the ability to isolate direct project costs from various indirect costs, including landlord activities. This was made difficult by numerous differences in cost estimating methodologies, planning methodologies, and accounting practices across the complex. With integrated planning efforts in their infancy, both within and between installations, huge gaps in data and

multiple potential sources of data required decisions as to which data sources would be used and how data gaps would be filled. Prior to this analysis, there also was no central repository for critical data.

Given the uncertainties, the Department developed a *Base Case Scenario* representing current views of the most likely set of activities and unit costs and several *Alternative Scenarios* to examine the potential impacts of various policy decisions on total program cost and schedule. For the Base Case, cost and schedule estimates are based primarily on installation-specific (field) data, supplemented with parametric modeling (Headquarters) only when necessary to fill data gaps. Alternative scenarios used field data where available but relied primarily on parametric modeling.

C.2.1 Gathering Data

Obtaining an integrated cost and schedule estimate required eight basic types of data for each Environmental Management activity (Table C.6). Data on phases, cost and duration were used to estimate activity cost and duration. Waste volume data were used to develop an integrated schedule of Environmental Management activities (e.g., to coordinate planned waste management facilities with estimated waste generation) and to estimate waste management costs. Technology data were used to evaluate the impact of technology development on cost and schedule estimates. Anticipating the potential need to re-schedule Environmental Management projects to accommodate funding and waste management constraints, it also was critical to understand which projects were governed by existing compliance agreements (to avoid creating a Base Case that was not in compliance with these agreements).

Environmental restoration activities are divided into three phases: Characterization and assessment (e.g., remedial investigations, feasibility studies), remediation or decommissioning, and post-remediation operation and maintenance (e.g., ground water monitoring, inspecting caps). Nuclear material and facility stabilization activities are divided into four phases: Pre-stabilization surveillance and maintenance, assessment, stabilization, and post-stabilization surveillance and maintenance. Waste management activities are divided into four phases: Pre-construction (including design, pilot testing, and permitting), construction, operation and maintenance, and decommissioning. Specific methods used to collect data for each of these types of projects are described in separate sections below.

Table C.6
Required Data for Each Activity

Identity and Location of each activity

Phases that describe the tasks required to complete the activity

Cost of each phase (annual)

Duration of each phase (years)

Schedule for starting each phase

Waste Volumes generated during each phase (annual)

Technologies used for each phase

Compliance milestones for each phase

C.2.1.1 Environmental Restoration Activities

The primary source of Base Case cost and schedule data for environmental restoration activities is existing *Baselines* developed at each installation (Table C.7). These Baselines incorporate the installations' assumptions regarding extent of contamination and ultimate remediation approach based on final land use assumptions. This approach allows the field offices, who know their individual installations best and have experience with their prospective regulators, to make the necessary assumptions for this analysis. Use of Baselines ensured that the resulting analysis was based on the strongest possible foundation and is the best approximation of future events at Department of Energy installations that can be made at this time.

The Department extended existing Baselines to full life-cycle where possible and supplemented these with parametric modeling as required to account for all present and future activities. Using a data call instrument developed at Headquarters, field offices extracted the elements listed in Table C.6 from the Baselines.

C.2.1.2 Nuclear Material and Facility Stabilization Activities

The cost and schedule estimates for nuclear material and facility stabilization activities are order-of-magnitude estimates and were obtained using parametric cost estimating techniques. The Environmental

Table C.7
Environmental Restoration Baselines

The process to baseline all Environmental Restoration activities began in 1991. That process included developing baselines for the customary budget planning horizon of seven years, performing detailed reviews of cost estimating methodologies and planning assumptions, obtaining Department of Energy approvals, and implementing change control procedures and updates as events have impacted those assumptions. Complete, life-cycle baselines are expected to be available for all installations by September 1995.

Baselines provide estimates and schedules for over 85% of the current scope of environmental restoration activities, which includes:

All known past practice waste sites and releases requiring evaluation and potentially remediation;

The portion of contaminated surplus facilities which have been deactivated but require decontamination and in some instances demolition or containment structures;

Construction of some specialized treatment, storage and disposal facilities to deal with unique wastes or special permitting; and

Other activities to support environmental restoration activities, including funds for grants to EPA, state regulators and tribes, landlord activities, and program management and support.

Management program has limited experience with which to base cost and schedule estimates for surveillance, maintenance, and stabilization of surplus facilities. In addition, uncertainty regarding the ultimate mission and/or disposition of many nuclear weapons production facilities has made it difficult to determine which facilities will become surplus and when transition activities will begin. Therefore, to address the total life-cycle cost requirement, specific cost and schedule assumptions had to be developed for nuclear material and facility stabilization activities (Table C.8).

Table C.8
Assumptions for Nuclear Material and Facility Stabilization Cost and Schedule Estimates

Based on past experience, the initial schedule developed for this report assumes 10 years of pre-stabilization surveillance and maintenance, followed by 5 years of stabilization, and then 2 years of post-stabilization surveillance and maintenance; this "10-5-2 scenario" is by no means *the* scenario that will be used for current and future surplus facilities.

Data for each facility represents the best information available from the Surplus Facility Inventory Assessment database as of December 1994.

Only surveillance, maintenance and stabilization activities are included in the estimate.

Surveillance and maintenance is assumed to be occurring during facility stabilization activities.

The cost of managing waste generated from stabilization activities includes extracting, removing, and packaging waste for transport to an appropriate treatment, storage, or disposal (T/S/D) facility; subsequent transportation and T/S/D costs are included in each installation's waste management cost estimates.

The Department used a four-step process to develop cost and schedule estimates for nuclear material and facility stabilization activities (Figure C.2). Although detailed, installation-specific, cost and schedule data were limited, the Department made maximum use of actual cost and schedule information obtained from the initial stabilization and maintenance activities that have been conducted at the Hanford, Rocky Flats, and Idaho installations. All information developed by Environmental Management Headquarters was provided to field offices for review to ensure that the resulting analysis was based on the strongest possible foundation. The four steps of the methodology employed to estimate nuclear material and facility stabilization activities are described below.

Figure C.2 Steps for Estimating Cost and Schedule for Nuclear Material and Facility Stabilization Activities

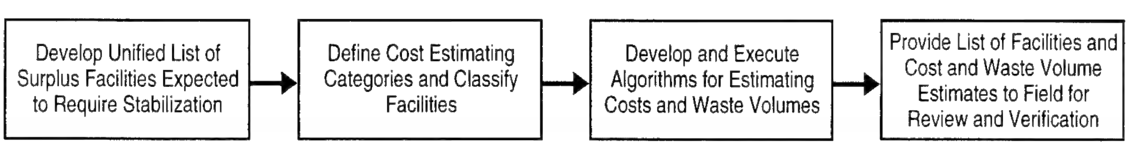


Table C.9
The Surplus Facility Inventory Assessment Data Base

The Surplus Facility Inventory Assessment data base accepts and stores data about the assets associated with each Department of Energy installation or operations. It also serves as a decision-making support tool to assist Department of Energy management with the transfer and disposition of surplus facilities.

Develop Unified List — The starting point for developing a unified list of surplus facilities was the Surplus Facilities and Inventory Assessment (SFIA) database (Table C.9). Three cases of contaminated facilities included in the SFIA database are expected to require stabilization and maintenance by Environmental Management. These cases include: (1) surplus facilities currently within the Environmental Management program; (2) surplus facilities that have not yet been transferred to Environmental Management, and (3) facilities that are expected to become surplus at some time in the future. The Department compared the SFIA with a list of surplus facilities developed for the Waste Management Programmatic Environmental Impact Statement. This comparison was necessary to link follow-on decommissioning cost estimates to the nuclear material and facility stabilization cost estimates. The reconciled lists were then reviewed by the field offices (see below). The resulting Unified List of approximately 3,500 facilities represents the best estimate of facilities likely to eventually require stabilization (as of December 1994). Nonetheless, the list is likely to contain uncertainties and inaccuracies, and further tuning is required for future reports. The Department is confident that all of the large facilities, which account for the bulk of the nuclear material and facility stabilization costs and waste volumes generated, are identified in the Unified List.

Define Facility Categories — To permit extrapolation of surveillance and maintenance costs from actual projects to the remainder of facilities on the Unified List, the Department identified 22 facility categories based on the type of historical activity performed at the facility and by its physical characteristics (e.g., stacks, pipelines, switchyards; Table C.10). These categories then were compared and reconciled with categories in the Waste Management Programmatic Environmental Impact Statement data bases and submitted to the field for review and verification.

Develop and Apply Algorithms — A separate algorithm for estimating cost and waste volumes was created for each of the 22 facility categories. Given the limited information available for many facilities, the Department used a simple approach based on multiplying the facility's physical characteristics (square feet, linear feet, gallons of facility size) by a unit cost (per square foot, linear foot, or gallon) to develop the cost estimates. Data on facility size generally were available in the Surplus Facility Inventory Assessment database and subsequently were verified by field offices. A description of the process used to develop each algorithm is presented in Section C.3.2.

Table C.10
Categories for Nuclear Material and Facility Stabilization Cost Estimates

Category	Description
A. Large Production Reactors	14 large reactors used to generate plutonium and tritium for nuclear weapons
B. Chemical Processing Buildings	Eight large plants ("canyons") used to chemically separate uranium and plutonium from other fission products
C. Diffusion Cascade Buildings	Three large facilities ("gaseous diffusion plants") used to remove and separate uranium 235 from uranium 238
D. Research Reactors	Smaller reactors used for research and development
E. Radiologically Contaminated Facilities	Other facilities contaminated with radioactive materials but not hazardous substances
E1 — size less than 1,000 ft^2	
E2 — size greater than 1,000 ft^2 and less than 15,000 ft^2	
E3 — size greater than 15,000 ft^2	
F. Radiologically Mixed Contaminated Facilities	Other facilities contaminated with radioactive materials and hazardous substances
F1 — size less than 1,000 ft^2	
F2 — size greater than 1,000 ft^2 and less than 15,000 ft^2	
F3 — size greater than 15,000 ft^2	
G. Hazardous Materials Contaminated Facilities	Other facilities contaminated with hazardous materials but not hazardous substances
G1 — size less than 1,000 ft^2	
G2 — size greater than 1,000 ft^2 and less than 15,000 ft^2	
G3 — size greater than 15,000 ft^2	
H. Special Nuclear Material Contaminated Facilities	Other facilities contaminated with special nuclear materials
H1 — size less than 1,000 ft^2	
H2 — size greater than 1,000 ft^2 and less then 15,000 ft^2	
H3 — size greater than 15,000 ft^2	
I. Storage Tanks	Above- and underground tanks used to store waste and other materials
I1 — tanks contaminated with radioactive materials	
I2 — tanks contaminated with hazardous materials	
J. Stacks	Facilities used as exhaust stacks for boilers and similar structures
K. Electrical Switchyards/Pads	Facilities used to house temporary generators, transformers, and other electrical service components
L. Pipelines	Pipelines used to transfer materials between facilities
M. Ponds/Retention Basins	Earthen structures used to hold effluent liquids

Field Review and Verification — Numerous discussions have taken place between Headquarters and the field regarding what facilities are on the Unified List, how these have been classified for cost estimation purposes, size and other key physical characteristics, types of wastes expected to be present, and waste volumes expected to be generated during stabilization. Many modifications of the Unified List have resulted from this review and verification effort. A variety of facilities were removed from the list, including those that already have undergone stabilization and those such as mobile offices that are unlikely to be contaminated. Cost and waste volume estimates for several facilities were modified based on updated information from the field regarding their physical, chemical, and radiological characteristics.

C.2.1.3 Waste Management Activities

The Environmental Management program is responsible for managing six types of waste and spent nuclear fuel. The approach for estimating life-cycle waste management costs depended considerably on the type of waste being managed. The Department currently has accurate estimates of the total volume of high-level waste and spent nuclear fuel for which the Environmental Management program is responsible. Plans for managing high-level waste are reasonably well advanced, and options for managing spent nuclear fuel are being evaluated in accordance with the National Environmental Policy Act process. Life-cycle costs and schedules for managing these two waste types thus are fairly well defined. Similarly, most of the hazardous waste and sanitary waste being managed by Environmental Management is generated by ongoing Department of Energy operations. Data on annual costs for managing these waste types are included in the site summaries (Volume II).

Low-level waste, low-level mixed waste, and transuranic waste present a different challenge. A significant fraction of the volumes of these three waste types requiring treatment, storage, and disposal will be generated by environmental restoration and nuclear material and facility stabilization activities. As noted earlier, it is not possible to predict how much waste will be generated, where and when it will be generated, where and when treatment and disposal facilities will need to be built, and how large these facilities will need to be until numerous decisions are made by the President, Congress, and citizens. Life-cycle cost estimates for waste management activities thus (a) depend directly on the life cycle estimates for environmental restoration and nuclear material and facility stabilization activities and (b) may change significantly as environmental restoration and nuclear material and facility stabilization activities, assumptions, decisions change. To provide a flexible cost and schedule estimating

approach, the Department used parametric modeling, calibrated to existing site planning information, for low-level waste, low-level mixed waste, and transuranic waste management estimates.

Program management costs for waste management activities are included as either a portion of the direct costs (for high-level waste, spent nuclear fuel, hazardous waste and sanitary waste) or through a multiplier applied to direct cost estimates (low-level waste, low-level mixed waste, and transuranic waste). The appropriate proportion is included in the waste management costs (see Section 3.2.1.5).

High-level Waste — The Department obtained cost and schedule data for managing high-level waste primarily from program planning documents, supplemented by data from Environmental Management Headquarters program staff. Planning estimates for high-level waste are available for Hanford (including the Tank Waste Remediation System), Savannah River (including the Defense Waste Processing Facility), the West Valley Demonstration Project, and the Idaho National Engineering Laboratory (including the Idaho Chemical Processing Plant). Cost and schedule estimates are partitioned into treatment, storage, and disposal activities and further divided into specific projects (e.g., high-level waste disposal, tank farm operations and maintenance). Cost estimates for high-level waste include the treatment and disposal of low-level waste resulting from treatment processes such as the saltstone facility at the Savannah River Site and a vitrification facility at Hanford. Decommissioning costs for high-level waste facilities were not included in program planning documents. Headquarters program staff provided estimates based on conceptual estimates for the Defense Waste Processing Facility.

Spent Nuclear Fuel — The Department obtained cost and schedule data for the spent nuclear fuel program from headquarters program staff supporting development of the Programmatic Environmental Impact Statement (EIS) for the National Spent Nuclear Fuel Program. As of March 1995, the Department has not identified a preferred option for managing spent nuclear fuel. The Department used a regionalized by waste-type scenario being evaluated for the EIS as the Base Case for this report. This Base Case estimate, partitioned into treatment, storage, and disposal activities and projects, includes full life-cycle costs, including facility decommissioning.

Hazardous and Sanitary Waste — The Department obtained cost and schedule estimates for hazardous waste and sanitary waste generated and/or managed by Environmental Management based on Activity Data Sheets for the years FY 1995 through FY 2000. Costs were adjusted to FY 1995 dollars using an assumed annual inflation rate of 3 percent. Costs then were compared with data provided by the field and adjusted accordingly.

The resulting average annual costs for each installation were assumed to remain constant (in FY 1995 dollars) until Environmental Management activities at the site are completed. Hazardous waste generated by environmental restoration and nuclear material and facility stabilization activities are assumed to be handled by the Environmental Management program and sent to a commercial vendor for treatment and disposal. Estimated cost is $2,000 per cubic meter, including handling and storage costs prior to off-site shipment.

Low-level Waste, Low-level Mixed Waste, and Transuranic Waste — The Department obtained cost and schedule estimates for low-level waste, low-level mixed waste, and transuranic waste through a combination of site planning information and parametric modeling. The Department obtained estimates of existing inventories and annual generation rates for low-level mixed waste from the Draft Site Treatment Plans developed to comply with the Federal Facility Compliance Act. Estimates of existing inventories and annual generation rates for low-level waste and transuranic waste were obtained from analyses in support of the Waste Management Programmatic Environmental Impact Statement. Data for these three waste types were supplemented with additional information from individual installations and are current as of December 1994.

The System Cost Model was used to integrate waste loads from all Environmental Management activities into a single treatment and disposal configuration for managing existing and estimated future waste loads. The model estimates the direct costs of planning, constructing, operating, and decommissioning new facilities for the treatment, storage, and disposal of these wastes types. It is also includes information on the operating costs of existing facilities. A description of this model is provided in Section C.3.1.

The Department obtained a total life-cycle cost estimate for the Waste Isolation Pilot Plant (WIPP) from headquarters program staff. This fully-loaded cost allows the System Cost Model to model WIPP disposal operations based on the estimated operational life predicted by the model.

C.2.1.4 Technology Development Activities

The Department obtained current (FY 1995) cost estimates for technology development activities from existing budget documents. Current funding is 5.75 percent of the total Environmental Management program budget. The Department assumed that technology development funding would continue at this percentage throughout the life of the Environmental Management program.

C.2.1.5 Support Activities

The Environmental Management program performs many activities in accomplishing its varied missions. Activities such as remedial actions, decommissioning, and constructing and operating waste management facilities contribute directly to these missions. The costs of these activities are accounted for in the primary sources of cost estimates for this report (i.e., environmental restoration Baselines, waste management program planning documents, Activity Data Sheets, other budget documents, and parametric models). However, these primary sources do not always account for all of the Environmental Management program costs and activities. Omitted activities typically are "support" activities such as surveillance and maintenance, program management, landlord and infrastructure, and human resources that are necessary to operate the Environmental Management program. The Department evaluated how support costs are accounted at each installation in order to ensure that all costs are accounted once, and only once, in this cost estimate. This section provides a definition of support activities, describes how they are accounted for in this cost estimate, and describes how the Department estimated their life-cycle costs.

Most support activities can be classified into five categories (Table C.11). There are several ways that the Department of Energy installations fund support activities, and these practices differ between installations. Thus,

Table C.11
Environmental Management Support Activities

Landlord/infrastructure — Activities associated with providing utilities, maintenance, and general infrastructure for the entire installation.

Program management — Activities include planning, monitoring, and reporting of ongoing activities; cost/schedule tracking; and clerical and other administrative support. This also includes grants to states and localities. Program management also includes related support activities such as providing furnished equipment and laboratory upgrades. Program management activities are reported separately at each installation and at Headquarters. However, 70 percent of Headquarters program management funding is transferred to field operations.

Surveillance and maintenance — Activities include routine security inspections, radiological surveillance, safety/fire inspections, security patrols, and maintenance of contaminated or formerly contaminated areas or facilities.

Other sitewide support activities — These costs include human resources, chief financial officer, executive direction, and procurement.

Program direction — The Federal full-time equivalents to oversee and manage Environmental Management operations in the field and at Headquarters. Although costs for these activities are accounted for at Headquarters, approximately 75 percent of this funding is transferred to field operations.

the accounting practices for costs associated with each of these activities were identified separately, categorized, and aggregated for this report. Four categories of support costs must be examined:

Direct support funding — Support activities specific to one Environmental Management program element are directly paid for by that element. For example, waste management costs include program management specific to waste management activities, and environmental restoration costs include surveillance and maintenance specific to environmental restoration activities.

- *Indirect support funding* — Activities that support more than one type of Environmental Management activity at an installation (e.g., human resources) often are indirectly funded. These costs are allocated to budgets for environmental restoration, nuclear material and facility stabilization, and waste management projects. Some infrastructure and other site-wide support activities are funded through this mechanism. If the activity supports all projects and activities at the installation, the cost is called an overhead cost. If the activity supports only some types of projects (e.g., environmental restoration) the cost is referred to as organizational burden.

- *Direct landlord funding* — The Environmental Management program has landlord responsibilities at 10 Department of Energy installations (Table C.12). Landlord responsibility implies that the Environmental Management program must fund some, but not necessarily all, infrastructure and site-wide support activity costs. Landlord funding at the Waste Isolation Pilot Plant and the West Valley Demonstration Project is included but not specifically identified in this total cost estimate.

- *Direct Headquarters funding* — Several categories of support are funded directly at Headquarters. These include Headquarters program management, program direction, and transportation management. Note, however, that the majority of Headquarters program management and program direction funding is transferred to field operations (see Table C.11)

Many support activities are funded through more than one of the above four categories. Thus, funds from all sources must be accounted for in order to accurately

Table C.12
Installations at which the Environmental Management Program has Landlord Responsibilities

Nuclear material and facility stabilization activities include or soon will include site-wide landlord responsibilities at seven installations:

- Energy Technology Engineering Center
- Hanford Site
- Idaho National Engineering Lab
- Mound Plant
- Pinellas Plant
- Rocky Flats Plant
- Savannah River Site

Environmental restoration activities include site-wide landlord responsibilities at three installations:

- Fernald Site
- Grand Junction Project Office
- Oak Ridge K-25 Site

Waste management activities include site-wide landlord responsibilities at two installations:

- Waste Isolation Pilot Plant
- West Valley Demonstration Project

assess the total cost of any Environmental Management activity. Disregarding either the directly or the indirectly funded portion would present an incomplete view of cost.

Some, but not all, support costs are accounted for in the primary sources of cost estimates for this report (Table C.13). Thus, cost estimates derived from these sources were adjusted to account for all support costs. The Department used variations of the following three-step process to estimate current and future costs for support activities:

- Determine the current distribution of costs;
- Assess the variability of each cost type with respect to total program budget and program maturity; and
- Use information from the first two steps to determine time- and size-dependent outyear support costs.

Table C.13
Support Costs Accounted for in Primary Sources of Cost Estimates

Data Source	Support Cost Category			
	Direct Support	Indirect Support	Direct Landlord	Direct Headquarters
Environmental restoration Baselines	Yes	Yes	Yes	No
Environmental restoration parametric model (ARAM)	No[1]	No	N/A	No
Waste management program and planning documents	Yes	Yes	N/A	No
Waste Management parametric model (SCM)	No	Yes	N/A	No
Nuclear material and facility stabilization parametric models	No	Yes	No	No

N/A = not applicable
[1]Added from environmental restoration Baselines

Estimating direct support costs — Cost estimates for environmental restoration activities included estimates of direct support costs. Cost estimates for waste management activities based on program and planning documents (i.e., costs for high-level waste, spent nuclear fuel, hazardous waste, and sanitary waste) also included estimates of direct support costs. Direct support costs, however, were not provided for waste management activities modeled using the System Cost Model (i.e., costs for low-level

waste, low-level mixed waste, and transuranic waste) and for nuclear material and facility stabilization activities. Direct support costs for nuclear material and facility stabilization activities were included in estimates of direct landlord costs (see below). Direct support costs for activities modeled using the System Cost Model were estimated as follows.

To estimate the current ratio of direct support costs to low-level, low-level mixed, and transuranic waste treatment, storage, and disposal costs, the Department examined budget data from the Progress Tracking System. Costs were disaggregated to a low level (by Activity Data Sheet and Budgeting and Reporting Code), and expert judgment was used to associate each cost with a support or a direct waste management activity.

The resulting ratio of direct support costs to low-level, low-level mixed, and transuranic waste management activity costs was confirmed by Headquarters program managers.

To estimate how direct support costs might vary with respect to future changes in low-level, low-level mixed, and transuranic waste management costs, budget data were disaggregated further by function. Specific functions included program management, agreements-in-principle, waste minimization planning, environmental safety and health, corrective activities, general plant projects and upgrades, technology development, regulatory compliance, environmental monitoring, and tank farm operations (other than high-level waste). Headquarters program managers were surveyed regarding their judgement of the cost variability of each function with respect to changes in waste treatment, storage, and disposal (T/S/D) costs. From survey responses, a relationship of the following form was determined:

Support Costs (Year X) = A * T/S/D (1995) + B* T/S/D (Year X)

On average, estimated direct support costs in any year are the sum of 85 percent of FY 1995 T/S/D costs and 15 percent of the current year's estimated T/S/D costs.

Estimating indirect support costs — All sources of cost estimates accounted for indirect support costs except the Automated Remedial Assessment Methodology (ARAM). ARAM was not used extensively for the Base Case, but rather was used primarily to estimate environmental restoration costs for the Alternative land use scenarios (see Section C.4.2.2). Indirect support costs for activities modeled using ARAM were estimated as follows. Installation personnel completed questionnaires regarding FY 1995 - FY 2000 direct cost and total cost estimates for each Environmental Management program element present at the installation. The average ratio of indirect costs to direct costs was calculated from these questionnaires. Questionnaires were completed by personnel at

installations that comprise approximately 90 percent of Environmental Management costs. Data gaps were filled using either the average ratio for installations managed by the same Operations Office or by the complex-wide average ratio. The composition of indirect costs were obtained from the Allocable Cost Report, which classifies overhead costs into eighteen common categories.

Estimating direct landlord costs — Life-cycle estimates of site-wide landlord costs were obtained from installation personnel and reviewed by Headquarters program managers. Estimated costs were re-evaluated if estimated landlord costs as a percentage of total Environmental Management costs fluctuated dramatically from year to year, seemed implausibly high, or appeared unrealistic. Estimates for two installations (Savannah River and Hanford) were prepared by Headquarters personnel based on their five-year cost projections. Landlord costs for nuclear material and facility stabilization activities also included direct support costs. Available information did not allow the Department to separate these two types of costs.

Estimating direct Headquarters support costs — The Department obtained estimates of direct Headquarters support costs from current budget estimates and best professional judgement regarding how these costs are likely to change as the Environmental Management program matures. Table C.14 lists the assumptions used for these estimates.

Table C.14
Assumptions Used to Estimate Support Activity Costs at Headquarters

Element	FY 1995 Funding Levels	Projected Funding Levels
Program Management	6% of total Environmental Management funding	6% of total Environmental Management funding through FY 2000
		3% of total Environmental Management funding from FY 2001 to FY 2020
		1.5% of total Environmental Management funding from FY 2021 until end of Environmental Management program
Program Direction	5.75% of total Environmental	5% of total Environmental Management funding Management funding throughout life of Environmental Management program
Transportation Management	$20 million	$20 million through FY 2020
		$10 million from FY 2021 to FY 2040
		$5 million from FY 2041 to FY 2060
		$2.5 million from FY 2060 until end of Environmental Management program

C.2.2 Assembling the Data

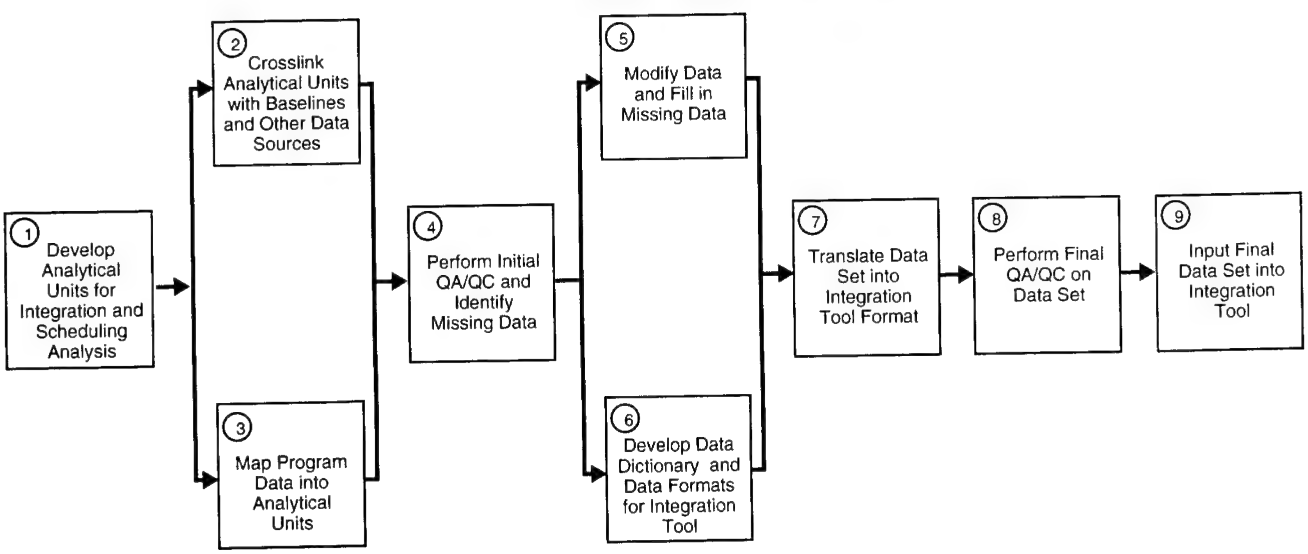
The Department used a nine-step process to assemble cost and schedule data prior to the integration/scheduling analysis (Figure C.3). Each step is described below.

Step 1 — Develop analytical units for integration and scheduling analysis

Information obtained from Baselines and other data sources included anticipated starting dates for each Environmental Management activity. The Department anticipated a need to revise these start dates in order to meet anticipated funding restrictions, allow for capital costs of new waste management facilities, and ensure that remediation and nuclear material and facility stabilization projects that would generate waste would be coordinated with waste management capacity. The Department therefore compiled information for each activity into analytical units for purposes of integration and scheduling. Most of the analytical units corresponded directly to the Environmental Management activities defined earlier (see Section C.1.2.1). Exceptions are described below.

Environmental restoration subprojects — The analytical units for environmental restoration activities were defined at the "subproject" level rather than the activity level to provide more flexibility in the integration and scheduling analysis. The 147 environmental restoration activities were subdivided into 614 subprojects. Each element included total cost less program management and directly-funded landlord costs.

Figure C.3 Steps in Assembling Data



Facility surveillance and maintenance activities — The 3,560 individual surplus facilities in the Unified List were grouped into 114 activities. Large facilities were reported individually; smaller facilities were grouped by geography and category. Decommissioning subprojects (from environmental restoration activities) were linked to each activity. Each activity included total cost less program management and directly-funded landlord costs.

Waste management activities — The initial list of waste management activities consisted of individual units for high-level waste, spent nuclear fuel, hazardous waste, and sanitary wastes at appropriate installations and existing treatment, storage, and disposal (T/S/D) facilities for managing low-level waste, low-level mixed waste, and transuranic waste. During the integration/scheduling analysis, the Department expected to add "new" T/S/D facilities to manage low-level waste, low-level mixed waste, and transuranic waste generated by environmental restoration and nuclear material and facility stabilization activities. Each new facility represented a new activity and included total cost less program management and directly-funded landlord costs.

Step 2 — Crosslink analytical units with Baselines and other data sources

It was necessary to crosslink analytical units with Baselines, parametric model data bases, and other data sources in order to develop a complete and integrated set of data on Environmental Management activities. Crosslinking efforts focused in three areas. (1) Environmental restoration subprojects (defined from Baselines) were linked to a data base of release sites (source areas) used by the Automated Remedial Assessment Methodology (ARAM) to ensure that missing data could be supplemented and to assist in calibrating ARAM for use in alternative land use scenarios (see Sections C.3.1 and C.4.2.2). (2) Environmental restoration decommissioning subprojects were linked to the Unified List of surplus facilities to ensure that decommissioning costs and schedule estimates were matched to nuclear material and facility stabilization cost estimates. This crosslinking effort also was used to further refine the list of facilities for which the Environmental Management program eventually will be responsible. (3) Data on existing and planned waste management facilities (obtained from the field) were placed and updated in the System Cost Model data bases to ensure that the cost, schedule, capacity, and location of these facilities were accurately incorporated into the scheduling analysis.

Step 3 — Map data from Baselines and other sources into analytical units

Concurrent with the crosslinking process, the Department mapped data from Baselines and other sources into the analytical units. As noted above, key data included duration, annual cost, annual waste volumes by type, anticipated start date, and whether or not any portion of the element was included in a compliance agreement (see Table C.6).

Step 4 — Perform initial quality assurance/quality control of data and identify missing data

Following the above data mapping step, the data in each analytical unit were reviewed by Headquarters staff to provide quality assurance/quality control checks. Missing and problematic data were identified.

Step 5 — Modify data and fill in missing data using parametric models

Missing data were filled and problematic data were filled and modified based on review comments and incorporated into the analytical units. Additional rounds of review and quality assurance/quality control were performed as necessary.

Step 6 — Develop data dictionary and data formats for input to integration tool

Concurrent with the data modification process, the Department developed a set of specifications for loading data to an integration tool being developed to assist in the integration and scheduling effort (see Section C.3.2). These specifications ensured that the data provided to the integration tool would accurately match data in the analytical units.

Step 7 — Assemble preliminary data set for input into integration tool

In this step, the Department translated data from the analytical units into the integration tool data formats.

Step 8 — Perform final quality assurance/quality control on input data

In this step, the Department loaded the translated data into the integration tool and used these data to debug the integration software and provide a final quality assurance/quality control check on the input data. Missing or problematic data were provided or modified accordingly.

Step 9 — Assemble final data set for input to integration tool

Following extensive review and quality assurance/quality control checks, the final set of data representing the Base Case was assembled and loaded into the integration tool data bases.

C.2.3 Checking and Documenting Data

Throughout the data assembly process, the Department performed a variety of efforts to ensure that the data used for the integration and scheduling analysis were the most accurate and complete representation of the Environmental Management program that could be provided to date. Data from all available sources were checked to ensure completeness, avoid double-counting, and ensure smooth integration of data from Baselines versus other sources. Internal consistency checks included a mass balance accounting to ensure that all waste assumed to be generated is assumed to be treated, stored, and/or disposed, particularly when transfer from one installation to another is anticipated. Projected waste volumes generated from environmental restoration and nuclear material and facility stabilization activities were reviewed by program managers to ensure consistency with installation- or facility-specific processes.

C.2.4 Limitations and Next Steps

The two most important limitations associated with gathering and assembling data for this initial cost and schedule estimate are data integration and data quality.

Limitations in data integration — The Department faced a number of challenges during the process of merging and integrating information from a variety of data sources into a single data base. Security concerns during the Cold War led to development of a compartmentalized and secretive management structure in the Department of Energy and its predecessor organizations. Although the Department presently is moving toward more openness and coordination, the planning process is not yet fully integrated at installations or Headquarters. Although it is moving toward fully integrated life cycle cost and schedule estimates, the process for developing Environmental Management Baselines is not yet complete. Moreover, developing this report has required a new and different type of integration. Because this report represents a new way to present the Environmental Management program, the data requirements for this report and the tools used to develop the Base Case scenario were not refined fully while this initial estimate was being prepared. Compartmentalization has led to multiple definitions for the same terms, differences in cost accounting methodologies, and other inconsistencies. The Department will develop more focused data collection instruments and more consistent cost estimating and accounting practices for next year's submission.

Limitations in data quality — Factors that limit the ability of the Department to estimate the cost and schedule for environmental restoration activities include insufficient characterization of the nature and extent of environmental contamination and uncertainty regarding the effectiveness

and unit cost of projected technologies. Limitations on estimates for nuclear material and facility stabilization activities include uncertainty in the number of facilities that eventually will require stabilization, a lack of information concerning the condition of these facilities, and the small experience basis for scope and cost estimates. Factors limiting the ability of the Department to estimate waste management costs include uncertainty in the volumes and characteristics of wastes that will need to be managed, and uncertainty in the effectiveness and unit cost of projected technologies. More general limitations on data quality include uncertainty in infrastructure costs and uncertainty in productivity gains to be realized as the Environmental Management program matures. The Department will develop more specific data quality objectives and more activity-based cost estimates for next year's submission.

C.3 Developing and Calibrating Cost Estimating Tools

The Department used two types of cost estimation tools in developing this report. Three separate tools were used to develop cost and waste volume data for the Base Case and Alternative scenarios. Another separate tool was used to assist the Department in re-scheduling activities and projects to meet assumed funding or waste management capacity limitations. This section describes the cost estimation tools used and how they were modified or developed to provide cost and schedule estimates.

C.3.1 Modifications to Existing Cost Estimating Tools

The Department modified two existing tools to provide cost and waste volume data for environmental restoration and waste management activities. Each of these tools is described below.

The *Automated Remedial Assessment Methodology (ARAM)* was used primarily to provide environmental restoration cost and waste volume estimates for alternative land use scenarios (see Section C.4.2.2). ARAM also was used to supplement missing data to complete data sets for the Base Case (Table C.15).

Prior to its use for this analysis, ARAM was calibrated to existing Baselines at six major installations (i.e., Hanford, Idaho, Los Alamos National Laboratory, Oak Ridge, Rocky Flats Environmental Technology Site, and the Savannah River Site) representing the majority of environmental restoration costs. The calibration effort included site visits and intense data gathering to:

- Update information on source terms (i.e., release sites) with the most current field characterization information;

Table C.15
Automated Remedial Assessment Methodology

The Automated Remedial Assessment Methodology (ARAM) was developed for the Waste Management Programmatic Environmental Impact Statement. ARAM was developed initially to provide relative estimates of cost, labor requirements, and waste volumes generated from alternative environmental restoration activity scenarios. Given a set of environmental restoration goals (i.e., cleanup goals and points of compliance), ARAM algorithms will (a) select remedial technologies; (b) determine the effectiveness of each technology in destroying, removing, or immobilizing contaminants; (c) determine the amount and type of waste generated from using each technology; and (d) and estimate the cost and labor requirements for each technology.

ARAM is applicable to seven types of "release sites": contaminated soils, buried waste, contaminated ground water, contaminated surface water, buildings, and liquid containment structures. ARAM is composed of four modules.

Decision Logic Modules are used to select an applicable technology category based on the environmental restoration goals, type of release site, types of contaminants present, and geological/climatological setting.

Technology applicability rules are used to determine the constraints of applicability for each technology category.

Technology effectiveness algorithms are used to determine reductions in contaminant concentrations and waste volumes generated from applying technologies.

Cost and labor estimating factors are used to estimate cost and labor requirements.

- Expand the number of sites for which unique environmental condition profiles (e.g., rainfall, geology, groundwater location and flow) are available;
- Adjust decision methodologies to reflect each installation's assumed remedial technologies for specific releases; and
- Calibrate unit costs and media volumes (both primary contamination and secondary waste volumes) to reflect field estimates.

The *System Cost Model (SCM)* was used to provide cost estimates for treating, storing, and disposing low-level waste, low-level mixed waste, and transuranic waste (Table C.16). Prior to its use for this analysis, SCM was calibrated to program planning documents at six major installations (i.e., Hanford, Idaho, Los Alamos National Laboratory, Oak Ridge Reservation, Rocky Flats Environmental Technology Site, and the Savannah River Site) representing the majority of waste management costs. The calibration effort included site visits and intense data gathering to:

- Calibrate estimated operation and maintenance costs to actual costs at existing treatment, storage, and disposal facilities;
- Calibrate algorithms for studies and bench scale tests, demonstration, production, and operations to the installation's assumptions for facility design, construction, and operations costs; and

Table C.16
The System Cost Model (SCM)

The SCM was built from computer models and cost algorithms developed for the Waste Management Programmatic Environmental Impact Statement. The SCM uses parametric cost functions to develop costs for various treatment, storage, and disposal modules, reflecting planned and existing facilities at installations. It has the capability to model new facilities based on needed capacities over the program life cycle.

The System Cost Model (SCM) estimates life-cycle costs for designing, constructing, operating and decommissioning treatment, storage, and disposal facilities for low-level waste, low-level mixed waste and transuranic waste. The SCM also estimates cost of transporting wastes or resulting products from generator to treatment sites and from treatment to storage sites. The user is required to provide input data on the volume and nature of waste to be managed, the time period over which the waste is to be managed, and the configuration of the waste management complex (i.e., where waste generated at each installation is to be treated, stored, and disposed). The System Cost Model then uses conceptual facility design criteria and information on the nature and quantity of waste requiring management, to determine the type and size of new waste management facilities required to manage the waste. The System Cost Model then uses documented cost equations to estimate the costs of designing, constructing, operating, and decommissioning these waste management facilities.

Studies and bench scale tests — manpower during research, equipment, installation, project management before title I, and contingency related to studies and bench scale tests

Demonstration — manpower during demonstration, design, inspection, project management, construction (building structure, equipment, indirect), construction management, management reserve, and contingency related to demonstration

Construction costs — design, inspection, project management, construction (building structure, equipment, indirect), construction management, management reserve, and contingency related to production facility construction

Operation management — conceptual design, safety assurance, permitting under the National Environmental Policy Act, preparation for operations, and project management

Operation and maintenance — operations manpower, utilities, materials, maintenance, and contingency related to operating and maintenance; and

Decommissioning — manpower, surveillance and maintenance, assessment and characterization, environmental documentation review, operations, closure, and post-closure monitoring

- Develop multipliers to determine total waste management costs from modeled SCM costs.

The SCM algorithms estimate direct costs associated with constructing, operating, and decommissioning treatment, storage, and disposal facilities. A large part of the activities required to manage waste are not included in these direct costs (Table C.17). The Department obtained cost estimates for these additional activities from these six installations. These cost

estimates were translated into a percentage and used as a multiplier on SCM costs to provide and estimate of the total life-cycle costs for a given treatment, storage, or disposal facility.

A simple calibration factor was used to adjust the SCM estimates for the remainder of the Department of Energy installations. Total volumes of low-level waste, low-level mixed waste, and transuranic waste requiring treatment, storage,and disposal were identified. The SCM was used to estimate the direct costs of managing these waste volumes. Total cost was obtained by multiplying the SCM direct cost estimate by the average factor for non-SCM costs at the six large installations. The ratio of the resulting total cost estimate using SCM and the installation's total cost estimate was used as a calibration factor for these smaller installations. This calibration factor was used to estimate total costs for managing low-level waste, mixed low-level waste, and transuranic waste in the years after FY 2000.

Table C.17
Waste Management Activities Not Included in System Cost Model Algorithms

General plant projects
Corrective activities
Program control/support
Program direction
Waste minimization planning
Research and development
Agreements-in-principle
Routine surveillance and environmental monitoring
Waste characterization
Waste shipping
Waste immobilization
Training costs
Stakeholder involvement costs
Generator service costs
Health, safety, and surveillance costs
Permitting and compliance costs
Information management costs
New facility planning costs
Infrastructure costs/site maintenance
Other costs as specified by installations

C.3.2 Developing New Cost Estimating Tools

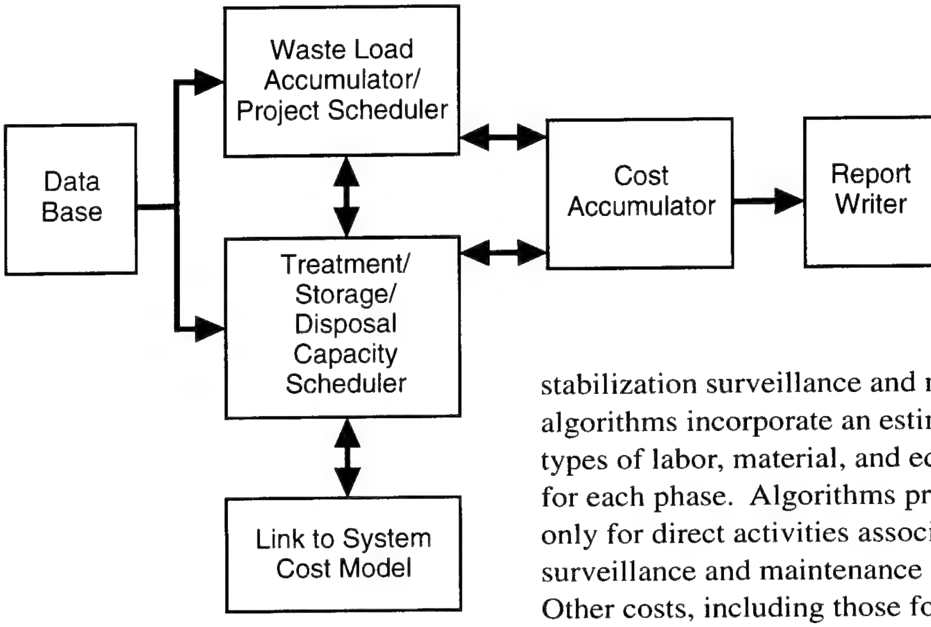
The Department developed two new cost estimating tools for this report. One was developed to provide cost and waste volume data for nuclear material and facility stabilization activities. The other was developed to provide the ability to re-schedule anticipated project starting dates to meet funding limits or to match waste generation with waste management capacity. Each of these tools is described below.

The Department used the *Micro Computer Aided Cost Estimating System* to develop and revise algorithms for estimating cost and waste volumes for nuclear material and facility stabilization activities (Table C.18). Specific cost algorithms were developed by reviewing walk-down reports, proposed stabilization standards, and existing stabilization estimates as well as interviewing headquarters and field representatives. Each algorithm provides cost estimates for the four phases of nuclear material and facility stabilization: Pre-stabilization surveillance and maintenance, assessment, stabilization, and post-

Table C.18
Micro Computer Assisted Cost Engineering System

The Micro Computer Assisted Cost Engineering System is a personal computer based cost estimating system developed for the U.S. Army Corps of Engineers and used for estimating environmental clean-up and capital construction project costs. It utilizes data bases which contain environmental line items, labor rates, material costs, and crew productivity rates. All data bases are fully adjustable to allow the cost estimator complete flexibility in developing the cost estimate.

Figure C.4 The Integration Tool



stabilization surveillance and maintenance. The algorithms incorporate an estimate of the specific types of labor, material, and equipment requirements for each phase. Algorithms provide cost estimates only for direct activities associated with facility surveillance and maintenance and stabilization. Other costs, including those for indirect activities and landlord, are estimated separately (see Section C.2.1.5).

The Department developed an *Integration Tool* to provide the ability to re-schedule anticipated project starting dates to meet funding limits or to match waste generation with treatment, storage, and disposal capacity. The integration tool was designed to assist in performing several of the steps required to develop the Base Case Scenario for this report. The integration tool consists of six main components (Figure C.4). The components and their relationships are described below.

Data Base (Step 1) — The data base contains all of the input data on cost, schedule, and waste volumes provided as inputs to the integration/ scheduling analysis. The data base is in ACCESS format.

Waste Load Accumulator/Project Scheduler (Steps 2 and 8) — The accumulator/scheduler sums up annual cost and waste volume data over time. The accumulator feature is used to sum the volumes of low-level waste, low-level mixed waste, and transuranic waste to be managed at each treatment, storage, and disposal installation. These volumes include existing wastes as well as wastes to be generated by environmental restoration, nuclear material and facility stabilization, and other Environmental Management or non-Environmental Management activities. Waste loads are directed from the installation at which they are generated to the installation at which treatment, storage, or disposal will occur using a pre-determined destination matrix. This matrix reflects information in low-level mixed waste draft site treatment plans (December 1994)

developed under the Federal Facility Compliance Act. The scheduler feature allows the user to input revised start dates for environmental restoration subprojects and nuclear material and facility stabilization activities. To assist users in selecting analytical units for re-scheduling, the scheduler displays the annual accumulated waste loads, costs, and schedule for each analytical unit.

Treatment, Storage, and Disposal (T/S/D) Capacity Scheduler (Steps 3 and 4) — The capacity scheduler compares annual waste loads to be managed at each designated T/S/D installation to existing and planned treatment, storage, and disposal capacity at these installations. If wasteloads exceed capacity, visual displays of data assist the user in dividing the excess capacity into "vintages" that define needed capacity for additional T/S/D facilities. The capacity scheduler tracks the volumes and estimates pre-treatment storage costs for waste volumes in excess of available capacity. The capacity scheduler also displays the costs, capacity, and schedule for existing and planned T/S/D facilities.

Linkage to System Cost Model (Step 5) — The capacity scheduler transfers information on the volume and timing of each waste "vintage" to the System Cost Model (SCM). The SCM estimates the life-cycle costs of new T/S/D facilities for treatment, post-treatment storage, and disposal of wastes in each vintage (see Table C.16). Schedule and cost for each new facility are transferred back to the integration tool as "new" waste management projects.

Cost Accumulator (Steps 6 and 7) — The cost accumulator aggregates cost output from the System Cost Model ("new" waste management facilities) with all other Environmental Management program costs to obtain a total cost estimate over time. The aggregated costs then can be compared with funding estimates at the installation and national levels.

Report Writer (Steps 8 and 9) — The report writer generates tables and graphs for this report directly from the data bases in the integration tool. This feature ensures that the results presented in this report are identical with those specified by the integration process and represented in the integration model data bases. Cost and schedule information can be reported in a variety of ways, including by installation, Environmental Management program element (e.g., environmental restoration, waste management), project phase (e.g., assessment, remediation, operation and maintenance), and waste type. Categories of cost also can be reported separately (e.g., landlord, program management, program direction, defense, non-defense).

C.4 Performing Scheduling Analyses

The Department performed a variety of integration/scheduling analyses for the Base Case and Alternative scenarios. This section describes the approach used for these analyses.

C.4.1 Base Case Scenario

The Department used a 10-step process to develop the Base Case Scenario for this report (Figure C.4). Each step is described below.

Step 1 — Input Data on Cost, Schedule, and Waste Volumes for Each Analytical Unit

The final set of data representing the Base Case scenario was assembled and loaded into the integration tool data bases.

Step 2 — Calculate Cost and Waste Volumes over Time

The input data for the Base Case scenario included estimates of when each activity or subproject would start and end, annual cost during that period, and annual waste volumes generated during that period. In this step, cost and waste volumes were summed to develop an initial schedule for Environmental Management activities. For low-level waste, low-level mixed waste, and transuranic waste, volumes summed were existing legacy

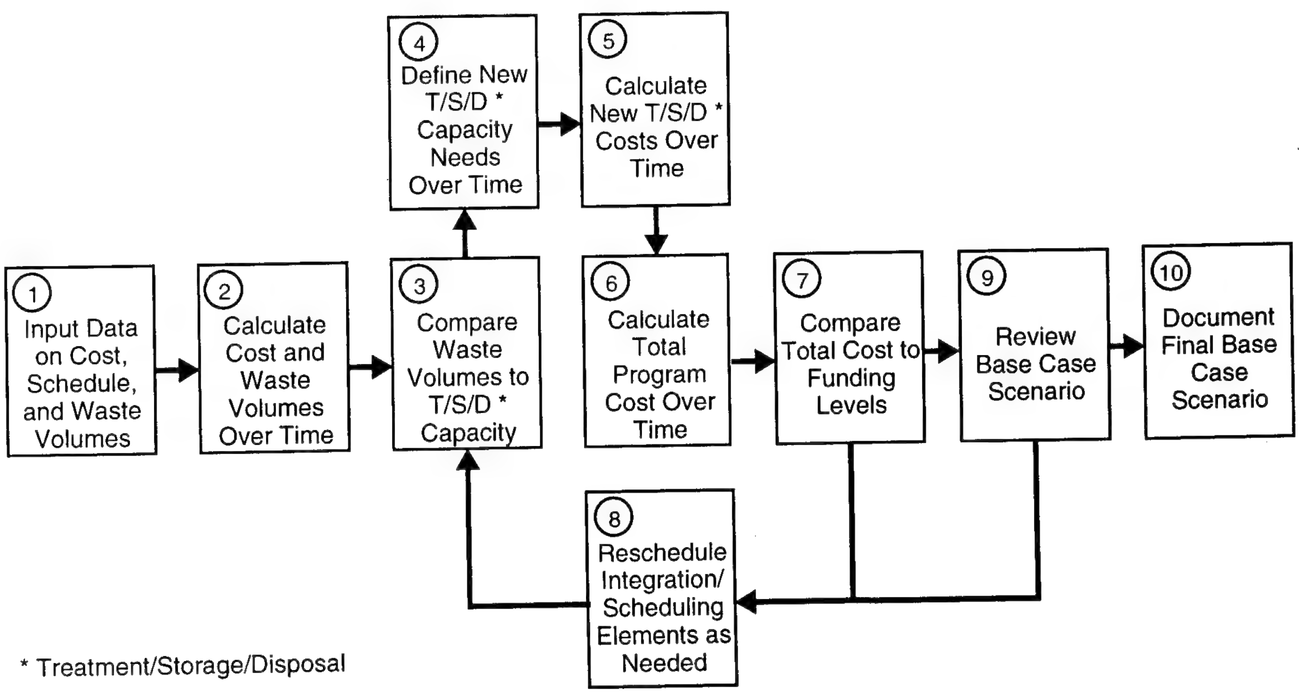


Figure C.5 Steps in Developing Base Case Scenario

wastes, annual waste loads from environmental restoration and nuclear material and facility stabilization activities, and annual waste loads from other Environmental Management and non-Environmental Management activities.

Step 3 — Compare Waste Volumes to Treatment, Storage, and Disposal (T/S/D) Capacity

The input data for the Base Case scenario was expected to be incomplete in terms of facilities needed to manage low-level waste, low-level mixed waste, and transuranic waste. The next step in developing an initial life cycle cost estimate was to compare the initial schedule for waste volumes generated with existing and planned T/S/D facilities in the input data. Where waste volumes did not match T/S/D capacity, either re-scheduling of activities/subprojects or new T/S/D facilities would be necessary.

Step 4 — Define New T/S/D Needs over Time (if necessary)

Where re-scheduling of activities or subprojects would be insufficient to meet T/S/D needs over time, estimates of new T/S/D capacity would be required. Each T/S/D can be assumed to have limits on lifetime and capacity. Therefore, where waste volumes were extremely large or were predicted to be generated for several decades, T/S/D capacity needs were partitioned manually into "vintages". Each "vintage" represents a portion of the waste load that can be managed at a single facility. The parameters of each "vintage" include the 5-year period in which pre-construction activities for the waste management facility would need to begin (e.g., 2000-2005, 2015-2020), the number of years that the facility could accept waste, and the annual volume of waste that could be managed at the facility. The number, size and temporal distribution of "vintages" at a given waste management installation depended on the distribution of waste loads over time.

Step 5 — Calculate New T/S/D Costs over Time (if necessary)

The System Cost Model (SCM) was used to calculate the life-cycle costs of designing, permitting, constructing, operating, and dismantling any new T/S/D facilities that would be needed to manage the waste volumes being generated.

Step 6 — Calculate Total Cost over Time

Annual costs for the new T/S/D facilities were added to the costs represented in the input data to derive an estimate of the total life-cycle Environmental Management costs and schedule.

Step 7 — Compare Total Program Cost to Funding Levels

The initial total program cost estimate was compared to assumed annual funding levels. Where costs exceeded or were less than funding levels, re-scheduling of activities was necessary.

Step 8 — Re-Schedule Analytical Units Needed

Individual activities or subprojects were re-scheduled manually to more closely match cost and funding estimates. Re-scheduling was performed by Department of Energy staff and discussed with Headquarters program managers. Steps 3 through 8 were repeated as necessary until total program cost matched assumed funding levels on an annual basis within a reasonable tolerance. This cost and schedule estimate was considered the initial Base Case scenario.

Step 9 — Review Base Case Scenario

The initial Base Case Scenario was reviewed by program managers at Headquarters and at field sites.

Step 10 — Document Final Base Case Scenario

The Department documented the final Base Case scenario based on programmatic review. Cost and schedule estimates, aggregated at the activity level, are presented in the individual site summaries presented in Volume II of this report.

C.4.1.1 Performing the Integration

The integration analysis was performed by Department of Energy staff. The integration and scheduling analysis was aimed at smoothing projected costs and waste generation rates to match available funding and waste management capacities. The only "new" activities generated during this process were treatment, storage, and disposal facilities needed to manage low-level waste, low-level mixed waste, and transuranic waste generated from environmental restoration and nuclear material and facility stabilization activities. Otherwise, the analysis only moved project starting dates for individual activities or subprojects back or forward in time.

Re-scheduling required to meet funding or waste management capacity limitations may result in a mis-match between the schedule and funding profiles for activities in this report and those in site Baselines or other source documents. Therefore, Baselines and other documents in reading rooms and elsewhere may not match up exactly with the Base Case in this report.

Certain general rules were used during the integration/scheduling process. Projects underway in 1995 or scheduled to begin from 1995 to 2000 were not re-scheduled. Projects which are governed by existing compliance agreements were not re-scheduled unless there were no other options for meeting funding limitations. No attempt was made to trade-off funding between installations (i.e., the flat funding assumption was applied to each installation).

C.4.1.2 Documentation

The Department developed a change control process for documenting all changes in the input data and in scheduled starting dates for projects and activities. This process included operator procedures to be used at the beginning and end of each session to document how the operator made changes in the data base; and data manager procedures to merge changes made by multiple operators into a single copy of the data base and to maintain appropriate configuration control.

C.4.1.3 Productivity and Discounting

Productivity initiatives in the Environmental Management program were initiated in 1993. Because these initiatives are recent, there are little historic data regarding Environmental Management productivity. For this reason, the Department looked to other industries and government organizations to determine typical productivity gains. These productivity improvements were then analyzed and used to adjust out-year cost estimates. The methodology for estimating productivity gains is described in Appendix D.

C.4.1.4 Limitations and Next Steps

The two most important limitations associated with performing the scheduling analysis are the format of analytical units used for the integration and scheduling analysis and the fact that the analysis was Headquarters-based.

Analytical unit format — The format selected for organizing data for each activity or subproject, while generally useful for re-scheduling, created some difficulties when large blocks of cost or waste volumes were involved because annual costs could not be reduced by "stretching" individual portions of projects. In reality, many large activities could be speeded up or slowed down to match available funding. For future reports, the Department will work to develop a more flexible format.

Headquarters-based integration — The time and resource constraints for developing this report precluded the direct involvement of field staff in the scheduling analysis. Although field staff reviewed the results, more direct

input would be preferable. As integrated planning at the installation level improves, future reports should involve a more field-based scheduling analyses.

C.4.2 Alternative Scenarios

The Base Case scenario incorporates a broad range of assumptions regarding the eventual outcomes of various decision-making processes that will determine the solutions applied to problems and the ultimate end states for Department of Energy facilities. The final cost and schedule for the Environmental Management program will depend considerably on decisions reached through processes specified in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Environmental Policy Act (NEPA), and other environmental laws. It is important to understand which decisions are likely to affect life-cycle cost and schedule significantly as well as the potential magnitude of these effects. Preliminary analyses suggested that four general categories of decisions have the potential to affect significantly the life-cycle cost and schedule for the Environmental Management program (Table C.19).

C.4.2.1 General Approach

The primary tools available for developing the Base Case scenario are inadequate for evaluating Alternative scenarios (e.g., Baselines and other bottom-up estimation techniques are not easily re-done with alternate assumptions). Ongoing processes such as negotiations over siting of waste management facilities under the Federal Facility Compliance Act are not examining the Environmental Management program as a whole or in a fully integrated fashion. Therefore, the Department needed to develop an alternate approach for examining the cost consequences of broad policy decisions.

Table C.19
Types of Decisions Likely to Affect Environmental Management Life Cycle Costs

Land Use — What ultimate uses should be permitted for currently contaminated lands and waters at each installation?

Funding and Schedule — How much money should be spent on Environmental Management activities and how rapidly should this money be spent?

Technology Development — What types of new technologies should be introduced and when should they be implemented?

Waste Management Configuration — At what installations will treatment, storage, and disposal of wastes occur?

With some modifications, the 10-step process used to develop the Base Case scenario (see Figure C.5) also was used to develop Alternative scenarios. The modifications generally consisted of either changing input data at the start of the process or assumptions at specific steps during the process.

C.4.2.2 Land Use

To provide an understanding of the range of costs associated with land use decisions, the Department developed two alternative land use scenarios. The *modified removal* case assumed that land use decisions would result in use of more active remediation technologies than assumed for the Base Case. This generally means that the remediation strategy would be designed to allow people to use these resources for any alternative purposes, including subsistence farming. The *modified containment* case assumed that land use decisions would result in use of more containment technologies than assumed for the Base Case. This generally means that institutional controls would be used to prohibit access to contaminated land or use of contaminated water indefinitely.

In order to add a measure of realism to the analyses, the more containment and more active remediation scenarios did not represent extreme, "pure" restricted or unrestricted land uses (i.e., the more active remediation scenario does not assume that the entire complex will be released for unrestricted use). Some Base Case land use (remedial technology) assumptions were unchanged, or in other words, "fixed" for the purposes of these analysis. Land use assumptions were fixed in these cases:

- Where a Record of Decision, contractual agreement or other legally binding decision document has been signed (such as Corrective Measures under RCRA or specific conditions in a Consent Order);
- Where the Department has ongoing or planned waste disposal activities (e.g., 200 Areas at Hanford);
- Where an installation is not owned by the Department of Energy and a contractual agreement dictates cleanup standards or future land use;
- Where the Department of Energy has promised to release an installation for specific uses (e.g., the Pinellas installation for industrial use); and
- Where remediation is not technologically possible.

The Department used the Automated Remedial Assessment Methodology (ARAM) to develop cost and waste volume estimates for environmental restoration activities under the two alternative land use scenarios. ARAM uses a technology selection logic to evaluate potential remedial technologies and select a most likely technology under each land use scenario (Table C.20). ARAM generally selects technologies that result in *in situ* (in-place) destruction or treatment of contaminants over excavation due to lower cost and worker risk. When *in situ* destruction is not technically feasible (e.g., for radionuclides or metals), ARAM technology selection varies for the two land use alternative. Leaving contaminants in place generally is incompatible for unrestricted land use, and therefore ARAM generally selects technologies that result in removal of contaminants for off-site treatment and disposal. Thus, the *modified*

Table C.20
Technology Selection Preferences for Unrestricted and Restricted Land Use Scenarios

Soil, Buried Waste, Ground Water, Surface Water

Unrestricted Land Use	Restricted Land Use
• In situ destructive technologies (thermal and nonthermal) are the first choice because they reduce concentration and/or inventory; leaving a monolith in place (e.g., in situ vitrification) is acceptable • Containment and in situ technologies that do not remove or destroy contaminants (e.g., caps, barriers, ground water access controls) are precluded because it is assumed that the Department cannot provide institutional control and long-term maintenance • Ex situ excavation, treatment, and disposal generally are selected	• In situ technologies are the first choice • Containment is preferred over in situ treatment when risk targets can be achieved • Ex situ treatment is a last resort

Liquid Containment Structures, Buildings

Unrestricted Land Use	Restricted Land Use
• All petroleum tanks are removed • All buildings, tanks, and other structures are cleaned and demolished for public safety • All contaminated rubble/debris is removed (cost of storage and/or disposal is included in waste management activities) • Clean rubble/debris is buried on site with additional fill to restore the site grade/contour	• All petroleum tanks are removed • All above-ground tanks are removed for safety reasons • Underground tanks are cleaned, filled with gravel, and capped • For all buildings, major equipemtn is removed, minimal decontamination (washing, blasting, scabbling) is performed, and the buildings are left standing in place

removal scenario included more removal technologies. In contrast, ARAM generally selects technologies that focus on containment rather than removal of contaminants for the restricted land use case. Thus, the *modified containment* scenario included more containment technologies.

Part of the ARAM calibration effort involved linking individual release sites in the ARAM data base to individual environmental restoration subprojects. This allowed the Department to aggregate revised cost and waste volume estimates (from ARAM) for the two land use cases at the subproject level for input to the integration tool. In essence, a replacement set of input data for environmental restoration activities was prepared for each of the two land use cases. These alternate data sets were input into the integration tool, and the integration and scheduling analysis was performed as outlined in Section C.4.1.2.

C.4.2.3 Scheduling

To provide an understanding of the range of costs associated with how future Environmental Management activities might be scheduled, the Department developed two alternative scheduling scenarios. For this analysis, input data for the Base Case remained unchanged, and different assumptions were used for the two alternative scheduling scenarios.

The first case *accelerated stabilization*, assumes that facility stabilization projects are accelerated to reduce surveillance and maintenance costs in the long term. Specifically, the assumed duration of pre-stabilization surveillance and maintenance was reduced from ten years to one year, and decommissioning was assumed to follow directly after stabilization (i.e., post-stabilization surveillance and maintenance was eliminated). Annual cost during the early years of the program thus increased, but total surveillance and maintenance costs decreased.

As a supplement to this case, the Department developed three case studies to indicate potential cost savings from accelerating some high-cost environmental restoration projects in order to complete all activities at an installation more quickly and thus minimize landlord costs. These case studies are for Rocky Flats, K-25, and Fernald.

The second case assumed *minimal action* in performing the following Environmental Management activities: restoration, decommissioning, and treatment and disposal of low-level, low-level mixed, and transuranic waste. Specifically, this case assumed that the program would focus on completing treatment and disposal of high-level waste and spent nuclear fuel and placing surplus facilities into a safe condition (i.e., facility stabilization), with no subsequent decommissioning. Existing volumes of low-level, low-level mixed, and transuranic waste would remain in storage,

and no environmental restoration activities would be performed unless specified in compliance agreements. Assumed pace thus would decrease during the early years of the Environmental Management program, with surveillance and maintenance activities continuing indefinitely.

For both alternative scheduling scenarios, the integration and scheduling analysis was performed as outlined in Section C.4.1.2.

C.4.2.4 Technology Development

This analysis focused on the savings potential from activities directly related to remediation, waste treatment and waste disposal costs and does not address costs associated with safeguarding plutonium, maintaining site infrastructure, program management, landlord, and long term surveillance and monitoring. Cost savings may be realized directly through decreased unit costs for remediation or indirectly through decreased waste generation (and subsequent management and disposal costs) as a result of applying these alternative technologies.

The Department analyzed the currently available remediation technology strategies assumed to be used for the *more active remediation* land use scenario to identify high payoff alternative technologies/systems. Technical Focus Area groups recommended improved, alternative strategies to replace the current strategies identified in the cost models. Unit costs of the alternative technology systems were developed to show cost savings compared with currently available technology systems. Based on this comparison, the Department calculated percentage savings and percentage impacts on waste volumes generated during the activity. These same technologies were used to analyze potential savings for both the Base Case and the more active remediation land use scenarios.

Identifying High-cost Technologies — The Department identified the set of technologies assumed for the more active remediation land use scenario using information from the Automated Remediation Assessment Methodology (ARAM) and the System Cost Model (SCM). ARAM was used to estimate cost and waste volumes associated with environmental restoration activities for the alternative land use scenarios. The SCM was used to estimate construction and operation costs for low-level mixed waste treatment and disposal facilities for all analyses presented in this report.

Identifying Alternative Technologies — The Technical Focus Area groups used the remediation strategies assumed for the more active remediation land use scenario to determine the appropriate alternative remediation/treatment technology or system with the potential for greatest cost savings. After selecting an alternative remediation/treatment strategy, the Technical

Focus Area groups described the operations in the process and determined which operations were likely to be deleted from or added to the remediation/treatment scenario. Process flow diagrams for the alternative strategies were developed to graphically illustrate the differences from the baseline. The cost savings from the use of alternative technologies/systems compared to the use of current technologies was estimated. The implementation time frame for the alternative strategy, an important aspect of this analysis, was also identified. Performance attributes were documented to determine the reliability and/or the degree of effectiveness of the alternative strategy for the relative contaminants.

The assumptions and operational impacts of using alternative technology systems were coordinated with the activities and requirements of environmental restoration and waste management activities. This coordination was important in resolving issues concerning the applicability of the new technologies, further defining the site geological conditions, and evaluating the overall treatment effectiveness. These discussions addressed shortcomings and limitations of the new technologies and any potential objections by stakeholders and the general public.

Estimating Unit Costs — The Technical Focus Area groups developed unit costs for alternative technologies to compare with unit costs in the cost models. The potential cost savings were based on a percentage of costs saved or on the percentage of waste volume reduced as a result of utilizing the alternative strategy. Industry information and technology demonstration cost and performance data provided the basis for unit costs of new and innovative, alternative remediation/treatment technology systems.

Estimating the Potential Cost Savings on Total Program Cost — A two-part process was used to estimate potential cost savings. The total cost for remediation and treatment using current strategies, was bounded at the low end by Base Case assumptions on land use and at the high end by the more active remediation land use scenario. The estimated total cost savings were reduced to allow for uncertainties in the technical applicability of a new technology to the specific characteristics of a project; regulatory and/or stakeholder acceptance of a new technology; and the cost of implementing a new technology. The technology systems examined for the Base Case assumptions included a plasma arc melter for mixed waste; efficient separation technology systems for high-level waste; in situ remediation technologies that avoid disposal costs; in-place soil and ground water remediation technologies; and facilities decommissioning. The more active remediation land use scenario included the suite of technology

systems identified for the Base Case plus additional remediation technology systems for buried waste problem areas. The following assumptions were used to implement this analysis:

- Environmental restoration technology data of Remedial Investigation/Feasibility Study (RI/FS) quality were not required in order to propose alternative remediation technology systems;
- Fully validated cost and performance data are limited for new technology systems; and
- Information on level of contaminants and geological/environmental conditions are limited.
- Only costs directly related to remediation, waste treatment and waste storage activities were evaluated. Program management, program direction and landlord costs were excluded.
- No escalation or discounting was included.

C.4.2.5 Waste Management Configuration

The Department of Energy has several strategic planning initiatives to determine the future configurations for storing, treating and disposing of wastes. These initiatives include the site treatment plans under the Federal Facility Compliance Act, the Waste Management Programmatic Environmental Impact Statement, and the National Spent Nuclear Fuel Programmatic Environmental Impact Statement. Each of these initiatives are aimed at providing decisions for where in the Department of Energy system wastes will be stored, treated or disposed (i.e., waste management configuration). The waste management configuration assumed in the Base Case was based on these current planning efforts. Cost estimates for alternative treatment and disposal configurations have been developed for the Waste Management Programmatic Environmental Impact Statement. Alternative configurations range from a centralized configuration, where most of the waste is treated at centralized facilities, to a decentralized configuration, where waste is treated at each generator site. A range of representative costs based on these alternative assumptions were provided for use in this report.

C.4.2.6 Limitations and Next Steps

The limitations associated with developing Alternative Scenarios depend on the particular analysis.

Land use — The primary limitations are the inability to evaluate other land use options (e.g., commercial/industrial, Native American) and the lack of maps dividing each installation into geographic sectors and identifying the future land uses still being considered for each sector. The Automated

Remedial Assessment Methodology (ARAM) could be improved to include a broader range of land use options. The Department will determine whether such an improvement is desirable for subsequent reports. As the future land use initiative continues, the Department expects stakeholders to begin identifying preferred land use options for each installation. Eventually, such preferences could be indicated on maps. Future reports will reflect progress toward this goal. A more general limitation is the lack of high-quality information on remedial options and their cost consequences at the installation level. The ARAM algorithms provide an estimate of the cost consequences of land use decisions from a nationwide perspective, but by necessity incorporate generalized and simplified calculations. Much more detailed site-specific information would be required to determine the actual cost of achieving various land use options at a given installation.

Scheduling strategy — The primary limitation is the lack of consensus on how to prioritize Environmental Management activities based on funding limits. The scenario represented in this analysis is based primarily on cost, and does not take include many other factors (e.g., risk) that normally would be considered in setting priorities. The Department will determine whether future reports would benefit from more specific alternate schedules.

Technology development — Analyses in subsequent reports will be refined by evaluating field data describing the clean-up strategy and cost for individual projects, analyzing geological information and descriptions of contaminants, and selecting specific alternative clean-up strategies that would reasonably apply. These more detailed analyses will then be aggregated to yield refined estimates of potential cost savings.

Waste management configuration — While a centralized approach may offer the lowest cost option, other considerations need to be assessed, such as transportation and environmental impacts, worker risk, and public risk. These will be examined as part of the Waste Management Programmatic Environmental Impact Statement and the Spent Nuclear Fuel Programmatic Environmental Impact Statement. This will form the basis for the Department of Energy and states to negotiate a configuration that is both cost effective and acceptable to stakeholders near the Department of Energy installations. Stakeholder input to the decision-making process is viewed by the Department as vital to determining a cost effective and equitable configuration for waste management facilities. Future reports will reflect progress toward this final decision.

C.5 Developing Documentation

The Department prepared this report to summarize the background for this effort, methods used to develop life cycle estimates for the Base Case and alternative scenarios, and results of the analyses. The report was prepared by Headquarters staff and reviewed throughout Headquarters.

The Department also prepared individual reports for each installation (Volume II). These include background information about the installation, description of the problems being addressed by the Environmental Management program, and descriptions of the types of remedies assumed to be used for each problem. Results of the Base Case analysis also are reported by Environmental Management program element, activity level, and cost category. Headquarters activities are reported in a separate installation summary. Installation summaries were reviewed throughout Headquarters and the field.

C.6 Peer Review and Stakeholder Involvement

One of the key objectives for this report is for its cost and schedule estimates to be clear and understandable. Congress also set forth a requirement in the FY 1994 National Defense Authorization Act for the Department to provide for stakeholder involvement in preparation of this report. To help ensure that this report met these obligations, the Department established a process for informing stakeholders about this report and its preparation, providing some stakeholder input in its preparation, and obtaining peer review of the process and tools used to prepare the total program cost and schedule estimates. Both of these efforts were challenging due to the magnitude of effort required and limited time available to assemble data, perform the integration/scheduling analysis, and document the process and results in this report. Moreover, many of the methodologies, approaches, and data sets necessary to complete this report were actively being revised in January through March of 1995. Nonetheless, the Department considers external peer review and stakeholder involvement critical to the credibility of cost and schedule estimates presented in this and all subsequent reports.

C.6.1 Peer Review Process

The peer review process included two key elements: a technical review of key tools used to provide cost and schedule estimates, and an administrative review of the process used to develop this report. The objective of the technical review was to determine whether cost and schedule estimates were comprehensive and objective, given the

uncertainties involved. The objective of the administrative review was to determine whether the process used to develop this report was adequate and reasonable, given the magnitude of the task and limited time available.

Technical Review — The Department obtained external peer review of the three key calculation tools used to develop this report: the Automated Remedial Assessment Methodology (ARAM) used for environmental restoration costs; the System Cost Model (SCM) used for waste management costs; and the integration tool used for the integration and scheduling effort. The general approach used for each peer review was to provide reviewers with all pertinent background documents (e.g., reports, manuals) and to hold a 1-2 day meeting where the developers and reviewers could discuss the tools in detail.

Two independent peer reviews of ARAM were conducted. Experts in remedial technology conducted a general review of the logic diagrams used to select remedial technologies and the unit cost estimates in ARAM. Experts in nuclear facility decommissioning reviewed all parts of the ARAM model relating to these activities. Experts in low-level, low-level mixed, and transuranic waste treatment, storage, and disposal reviewed SCM algorithms for the Waste Management Programmatic Environmental Impact Statement. Experts in developing complex models reviewed the approach used to develop the tool, the algorithms used in the tool, and the interfaces and reports generated to assist the users.

Administrative Review — The Department is in the process of obtaining external review of the administrative process used to develop this report. The review is being conducted by fellows of the National Academy of Public Administration (NAPA) and experts (identified by NAPA) in administrative tasks of similar magnitude and scope. The Department provided reviewers with all pertinent background documents (e.g., reports, manuals) and a review draft of the report. NAPA staff also interviewed key individuals involved in preparing this report both at Headquarters and the field. The peer review panel was briefed by project staff members.

C.6.2 Stakeholder Involvement Process

The Department divided responsibility for stakeholder involvement between Headquarters and field offices. Field offices were responsible for ensuring that the views of stakeholders were accurately reflected in the Base Case scenarios provided as input data. Processes such as negotiations leading to compliance agreements, environmental impact statements under the National Environmental Policy Act, and Records of Decision (RODs) under the Comprehensive Environmental Response, Compensation, and Liability Act require stakeholder input into final decisions reached by the Department of Energy and regulatory agencies. Input data from installations include remedial actions and timetables laid out in existing

agreements such as RODs and compliance agreements. In addition, the primary source of input data for environmental restoration activities, Environmental Management Baselines, are available in public reading rooms at each installation. Where such agreements do not exist (e.g., for future activities), installations used the recent history of such agreements to predict the likely outcome of future decision-making processes.

Department of Energy Headquarters was responsible for stakeholder involvement at a more national level. Information on the requirements, assumptions for, schedule for, and preliminary results of this report was provided to stakeholders at several meetings (Table C-21). Minutes of each meeting, including commitments by the Department to incorporate specific stakeholder comments, were prepared and distributed to all attendees. While these meetings were primarily informational, the Department did incorporate specific stakeholder suggestions in this report to the fullest extent possible.

C.6.3 Limitations and Next Steps

The timing of the peer review process and stakeholder meetings, coupled with the limited time available to prepare this report, made it difficult for the Department to respond to all suggestions or criticisms raised by reviewers and stakeholders. In many cases, for example, existing tools did not allow the Department to perform specific analyses or to perform a given analysis differently. Many comments, therefore, must be addressed in future reports. Individual installations will get more detailed stakeholder involvement in the assumptions process. The Department currently is working on a process to produce integrated teams at sites that will include stakeholders.

Table C.21
Stakeholder Meetings

April 18, 1994 — The Department held a kick-off meeting with stakeholders in Washington, D.C.

April 1994 to February 1995 — The Department held meetings and briefings with Office of Management and Budget and Congressional staff in Washington, D.C.

October 28, 1994 — The Department met with members of the Environmental Management Advisory Board in Washington, D.C.

November 30, 1994 — The Department met with members of the Western Governor's Association in Las Vegas, Nevada

December 1-2, 1994 — The Department met with representatives of the National Governor's Association and other stakeholder groups in Salt Lake City, Utah

February 2, 1995 — The Department met with members of the Environmental Management Advisory Board in Washington, D.C.

February 14-15, 1995 — The Department met with members of installation Site Specific Advisory Boards in Washington, D.C.

D. Effects of Productivity and Discounting on the Base Case

APPENDIX D
Effects of Productivity and Discounting on the Base Case

D.1 Incorporating Productivity into the Base Case

Several initiatives within the Environmental Management program are geared towards increasing worker productivity to reduce costs. Short-term initiatives are aimed at reducing indirect and overhead costs, contract reform, privatization, and streamlining. Through these initiatives, Environmental Management intends to cut costs 20 percent by FY 2000. Studies internal and external to the Department of Energy indicate that this goal is reasonable.

Longer term cost savings initiatives are aimed at developing and adopting new, cost-effective technologies and worker learning. Historical data from government agencies and private firms indicate that worker productivity should increase at an annual rate of 1-2 percent in the longer term. This section provides examples of Environmental Management's efforts to increase productivity, estimates the potential savings achievable through them, and shows their impact on the Baseline Report cost estimate.

D.1.1 Description of Environmental Management Productivity Initiatives

The Environmental Management program has set a goal of cutting costs 20 percent by FY 2000 with no decrease in work scope. Through annual performance plans and the FTE Bid Process Implementation Plans, Operations Office have outlined how they will meet these productivity improvement goals. Operations Offices have identified nearly $300 million in productivity savings that they intend to achieve in FY 1995. The Department of Energy will hold Operations Offices responsible for achieving their goals at the end of the fiscal year. Although FY 1994 savings were not tracked formally, preliminary estimates suggest that Environmental Management saved about $60 million through working smarter and being more productive in that year. A major contributor to these savings was the implementation of a waste minimization program at the Savannah River Site that reduced costs by more than $20 million in FY 1994 alone.

Environmental Management also has implemented plans to improve performance through improved contractor oversight under the belief that contractors will perform better if Environmental Management takes past

performance into account when making budgetary and policy decisions. Toward this end, Environmental Management has begun performing contractor assessments, in particular, the Cost Quality Management Assessments. Environmental Management performed these performance assessments in FY 1992 and FY 1994. These assessments provide Operations Offices with ideas on how to improve productivity and an incentive to improve (i.e., fact that their performance is being monitored and evaluated). By holding contractors accountable for their performance and incorporating it into decision making, Environmental Management is becoming a more demanding customer.

D.1.2 Short-Term Productivity Savings

To estimate the savings the Department could achieve through short-term initiatives aimed at reducing indirect and overhead costs, contract reform, privatization, and streamlining, Environmental Management reviewed internal and external studies. Internal studies indicate that there is room for productivity improvement in the program. External studies indicate that initiatives similar to those Environmental Management is implementing have the potential to spur productivity gains.

After years of neglecting environmental issues due to the need to produce weapons for the Cold War, the Department initiated an Environmental Management program. As the program developed, the emphasis was on establishing a program quickly rather than doing so in a cost-effective manner. This lack of emphasis on cost effectiveness has resulted in practices like multiple layers of contracting, inappropriate contracting mechanisms, and insufficient Government oversight. Stories analogous to the $500 hammers abound.

A study performed for the Department by Independent Project Analysis in November 1993 provides a quantitative estimate of cost-saving opportunities. It states that environmental restoration projects cost 32 percent more than those of their private counterparts and 15 percent more than comparable projects in other Government agencies.[1] This indicates that there is room for increasing Environmental Management efficiency.

Even before the results of this study were known, Environmental Management had initiated programs to reduce costs by increasing worker productivity. Contracting reform is a major part of this program. Because most of the Environmental Management program is contracted out, contract reform offers large cost saving opportunities. This is particularly

1 Independent Project Analysis, Inc. The Department of Energy Office of Environmental Restoration and Waste Management Project Performance Study, (Reston, VA, 1993).

true because a large portion of Environmental Management cost is not for exotic waste management and cleanup technologies, but for everyday goods and services (training, security services, personnel and human resource departments, and maintenance).

External studies on contracting also support the idea that increased competition stemming from contracting reform and improved oversight can reduce the Department's costs. Former Defense Secretary McNamara testified before the House Committee on Armed Services in 1965 that the introduction of competitive procurement into Department of Defense contracts resulted in an average savings of 25 percent to the government.[2] Also, a recent study of the Postal Service found that third-class mail costs would be 26 percent less expensive if the Postal Service operated in more competitive markets.[3] External literature indicates that cost savings from improved management and contracting reform can be substantial.

A goal of 20 percent cost savings by FY 2000 is realistic and achievable. Achieving this goal and sustaining these savings over the life cycle of the program will reduce the life-cycle cost of the program from $350 billion to $281 billion, a savings of $69 billion over the life cycle of the program.

D.1.3 Longer Term Productivity Savings

In the long term, the Environmental Management program has the potential to realize significant cost savings through worker learning and the application of new technologies. Learning theory indicates that the repeated use of similar technologies and production techniques provides laborers the opportunity to master the appropriate skills, and supervisors the opportunity to adapt their management strategies to the technology. It also allows all workers the chance to suggest cost-saving process modifications, for example, those geared at waste minimization. These improvements increase productivity over time. The application of new, more efficient technologies can also lead to significant cost savings.

The Base Case assumes that Environmental Management productivity will increase, after FY 2000, at a rate similar to other Federal agencies. The mean annual productivity growth rate for Federal agencies is approximately 1 percent for the period from 1967 to 1992.[4] In the base case, the life-cycle cost of the program is $230 billion.

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2 U.S. House of Representatives. Armed Services Committee. Military Posture and H.R. 4016," hearings, February-March, 1965. 433-439.

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3 Lenard, Thomas. 1994. "The Efficiency Costs of the Postal Monopoly: The Case of Third-Class Mail." Journal of Regulatory Economics, 6:421-432.

Because productivity growth is hard to forecast precisely, Environmental Management also estimated the life-cycle cost of the program assuming two other productivity growth rates: 0 percent and 2 percent. The first alternative assumes that Environmental Management's long-term productivity initiatives are unsuccessful. In this case, the life cycle of the program is $281 billion.

The second assumes that Environmental Management's growth rate is similar to that of private firms.[5] There are several reasons to believe that Environmental Management's productivity would increase similarly to that of private firms. First, Environmental Management spends more of its budget—about five percent—on technology development than other agencies. Second, more than 90 percent of Environmental Management's work is performed by private contractors.[6] In this case, the life-cycle cost of the program will be $200 billion.

As can be seen from the cost differentials between the cases assuming different rates of improvement, incrementally increasing productivity in the long term has the potential to reduce life-cycle costs by more than 25 percent. Improving worker productivity is a key to keeping the cost of the program under control.

D.2 Effects of Discounting on the Baseline

Discounting converts a stream of costs incurred over time to a single present value. The process of discounting does not affect the size of the appropriations necessary to pay for the Environmental Management program, it simply describes how this stream of costs is valued. This section discusses the method used to discount the life-cycle costs of the Environmental Management program.

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4 Bureau of Labor Statistics. Productivity Measures and Selected Industries and Government Services. March 1994 productivity growth rates: 0 percent and 2 percent. The first alternative assumes that Environmental Management's long term productivity initiatives are unsuccessful. In this case, the life-cycle cost of the program is $273 billion.

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5 American Productivity and Quality Center. Multiple Input Productivity Indexes. December 1988.

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6 National Science Foundation, Selected Data on Federal Funds for Research and Development: Fiscal Years 1992, 1993, and 1994, NSF 94-311 (Arlington, VA, 1994); Clinton, Bill, Budget of the United States Government: Fiscal Year 1994, April 8, 1993.

The most important step in determining a present value is finding a proper discount rate. The discount rate is the premium, expressed as a percentage, that makes a person indifferent between receiving a dollar today and receiving a dollar plus the premium next year. Because it is hard to precisely determine the appropriate rate, the Department found the present value using more than one. For the Baseline Report, discount rates of 3 percent and 7 percent were used to determine the present value of the program.

Three percent is a rate similar to those used by the U.S. Environmental Protection Agency. It is also similar to the social rate of time preference. The Office of Management and Budget recommends using a discount rate of 7 percent. This rate is the average real rate of return on private investment. The reason for using this rate is the belief that government expenditures crowd out private sector investments. Because consumption and investment are both opportunity costs of funds spent on the Environmental Management program, these rates bound the true rate.

The next step in discounting a stream of costs is calculating of present value. The following formula is typically used to determine the present value of a stream of costs:

Present Value = S[(AnnualCosts)/(1+i)]0n = Fiscal Year 1995

i = Annual discount rate (3 or 7 percent)

Annual cost is in constant dollars.

Since the Baseline Report database only provides post-year 2000 costs in 5-year periods, it was assumed that annual costs were the same for each year within the 5-year time frame. The assumption allows the use of the above formula in calculating the present value of the Environmental Management program. Using a 3 percent discount rate, the present value of Environmental Management life-cycle cost is $136 billion. With a 7 percent discount rate, the present value is $84 billion. This implies that the Government is indifferent between paying $84-$136 billion in FY 1995 for the program or paying the life-cycle stream of costs outlined in the Base Case.

E. Department of Energy Reading Rooms

APPENDIX E
Department of Energy Reading Rooms

Maria Hall
Morgantown Energy Techology Center
U.S. Department of Energy Library
3610 Collins Ferry Road
P. O. Box 880
Morgantown, WV 26507-0880

Library/Reading Room
U.S. Department of Energy
Dallas Support Office
1440 W. Mockingbird Lane, Suite 305
Dallas, TX 75247

Library/Reading Room
U.S. Department of Energy
Niper Library
220 North Virginia Avenue
Bartlesville, OK 74003

Library/Reading Room
Boston Support Office
ATTN: Hugh Saussy, Director
1 Congress Street
Boston, MA 02114-2021

Library/Reading Room
U.S. Department of Energy
Southeastern Power Administration
Samuel Elberton Building, Public Square
Elberton, GA 30635

Library/Reading Room
U.S. Department of Energy
Public Reading Room
Mailstop H2-53
P. O. Box 999
Richland, WA 99352

Library/Reading Room
U.S. Department of Energy
Nevada
2753 S. Highland Drive
Las Vegas, NV 89193-8518

Library/Reading Room
U.S. Department of Energy
Morgantown Energy Technology
Center Library
3610 Collins Ferry Road
Morgantown, WV 26507

Library/Reading Room
U.S. Department of Energy
Grand Junction Area Office
P. O. Box 2567
Grand Junction, CO 81503

Library/Reading Room
U.S. Department of Energy
Philadelphia Support Office
18th & John F. Kennedy, Jr. Blvd.
Philadelphia, PA 19102

Library/Reading Room
Idaho National Engineering
Laboratory
Pocatello Office
1651 Alvin Rickin Drive
Pocatello, ID 83201

Library/Reading Room
U.S. Department of Energy
Oakland Field Office
Wells Fargo Building
1333 Broadway
Oakland, CA 94612

Library/Reading Room
U.S. Department of Energy
Oak Ridge Field Office
200 Administration Road
Oak Ridge, TN 37831

Library/Reading Room
U.S. Department of Energy
Idaho Field Office
1776 Science Center Drive
Idaho Falls, ID 83415

Library/Reading Room
U.S. Department of Energy
Chicago Field Office
9800 South Cass Avenue
Argonne, IL 60439

Library/Reading Room
U.S. Department of Energy
Albuquerque
National Atomic Museum
P. O. Box 5400
Albuquerque, NM 87185-5400

Library/Reading Room
Cochran Mill Road, Building 95
P. O. Box 10940
Pittsburgh, PA 15236-0940

Public Reading Room
U.S. Department of Energy
Rocky Flats Public Reading Room
Front Range Community College Library
3645 West 112th Avenue
Westminister, CO 80030

Library/Reading Room
Department of Energy–Amarillo
P. O. Box 30030
Amarillo, TX 79120-0030

Library/Reading Room
U.S. Department of Energy
Forrestal Bldg., Room 1E-190
1000 Independence Avenue, S.W.
Washington, DC 20585

U.S. Department of Energy
Reading Room
Amarillo College
Lynn Library/Learning Center
2201 Washington Street
Amarillo, TX 79178

U.S. Department of Energy
Reading Room
Carson Ccounty Library
P. O. Box 339, Main Street
Panhandle, TX 79068

National Atomic Museum Building
Kirtland Air Force Base
U.S. Department of Energy
Public Reading Room
P. O. Box 5400
Albuquerque, NM 87185-5400